METAL PROGRESS

FEBRUARY, 1954

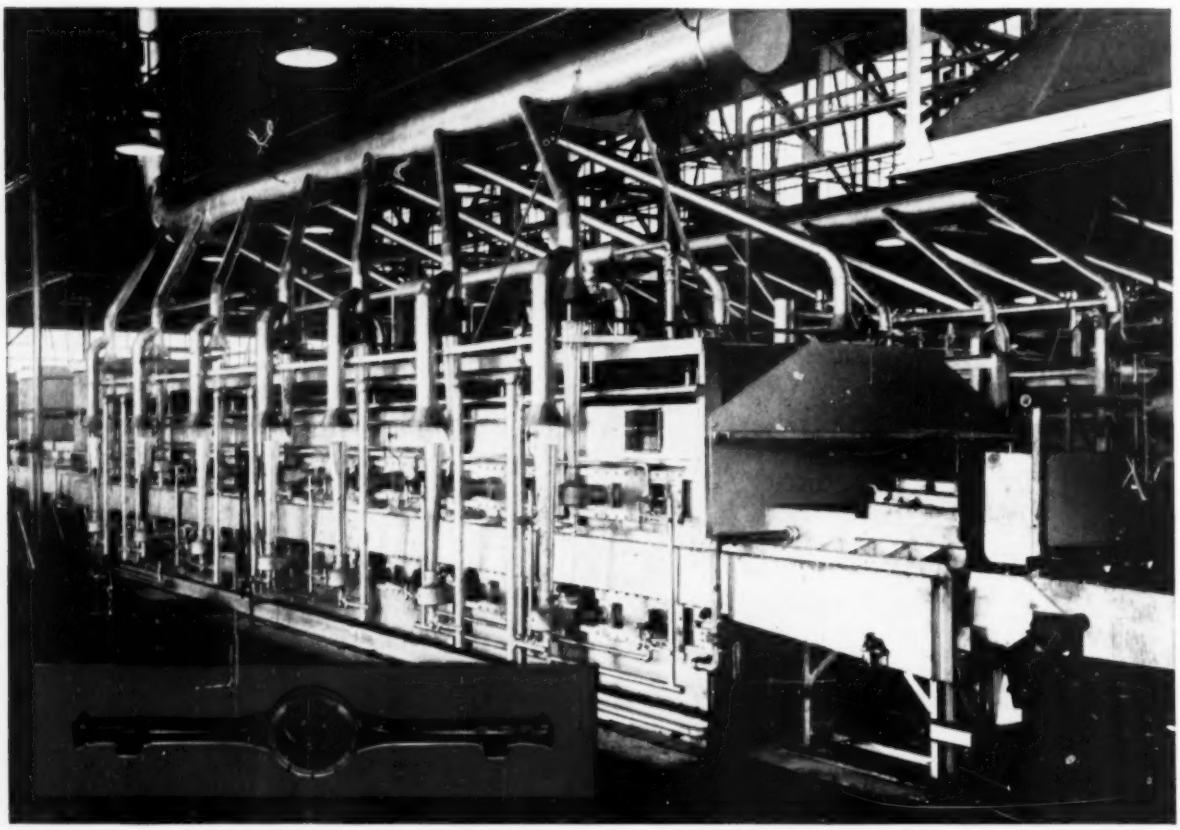
at five tons per hour

Ford Motor Company makes rear axle housings from welded steel tubing. Deformation in forming operations is so severe that the tubing must be clean annealed.

Two 'Surface' Roller Hearth Continuous Furnaces do the job for Ford at a rate of five tons of tubing per hour, per furnace. Radiant tube heating plus a 'Surface' controlled atmosphere (DX gas) prevents oxidation, eliminates the necessity of a pickling operation.

Shown below is the charge end of one of the 'Surface' Roller Hearth Continuous Furnaces. They are key components in this highly integrated production line that automatically cuts, forms, welds and anneals, rear axle housing tubes from coiled strip stock.

roller hearth furnace anneals steel tubing to take "the bends"



In more than a quarter century of use, 'Surface' Roller Hearths have demonstrated remarkable versatility in heat treatments on tubing, bars, coils, discs, sheets, both ferrous and non-ferrous — carbon restoration, heating for forming, annealing, high-speed stress relieving, hardening and drawing. They use direct firing, convection heating, or radiant tube indirect heating, all incorporating gas-saving, automatic proportioning burner equipment. Take advantage of 'Surface' experience and versatility to boost your production and profits.

Write for 'Surface' Literature Group H-53-3.

Surface
HEAT TREATING EQUIPMENT

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

ALSO MAKERS OF

Kathabar HUMIDITY CONDITIONING Janitrol AUTOMATIC SPACE HEATING

Metal Progress . . . . . February, 1954 Vol. 65, No. 2

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Cover by Carlos Vazquez

Engineering Articles

High-Speed Mill Forms, Induction Welds and Sizes Thin-Gage Nonferrous Tubing, by Thomas J. Crawford 65
Electrical Steel – A Triumph of Steelmaking, Heat Treatment and Scientific Metallurgy, by William Jones 70
Effective Heat Treatment of Molybdenum, by T. G. Perry, H. S. Spacil and John Wulff 75
Economic Survey of Seven Methods of Making Small Machine Parts, by Samuel Storchheim 77
James Bliss Austin – A Biographical Appreciation by Myron Weiss 82
Controlling Metal Quality at Ford's Cleveland Foundry 87
Dew Point – A Means of Measuring the Carbon Potential of Prepared Atmospheres, by Norbert K. Koebel 90
The Quality of Toolsteel – Historical Development, by Burns George 97
Dislocations, or What Makes Metals So Weak? by W. T. Read, Jr. 101
Frictional Properties of Titanium and Its Alloys by E. Rabinowicz 107
Introducing: The New Self-Lubricating High Speed Steels by Stewart G. Fletcher 161

Correspondence

Credit Where It Is Due, by Lee S. Busch 112
Chromium Diffusion Into Steel, by T. Bishop 112
Claims Statement on Zr Alloys Is Contrary to General Rule, by S. T. Quaass 112
Statement on Zr Alloys Not Meant to Be Revolutionary, by Earl T. Hayes 114

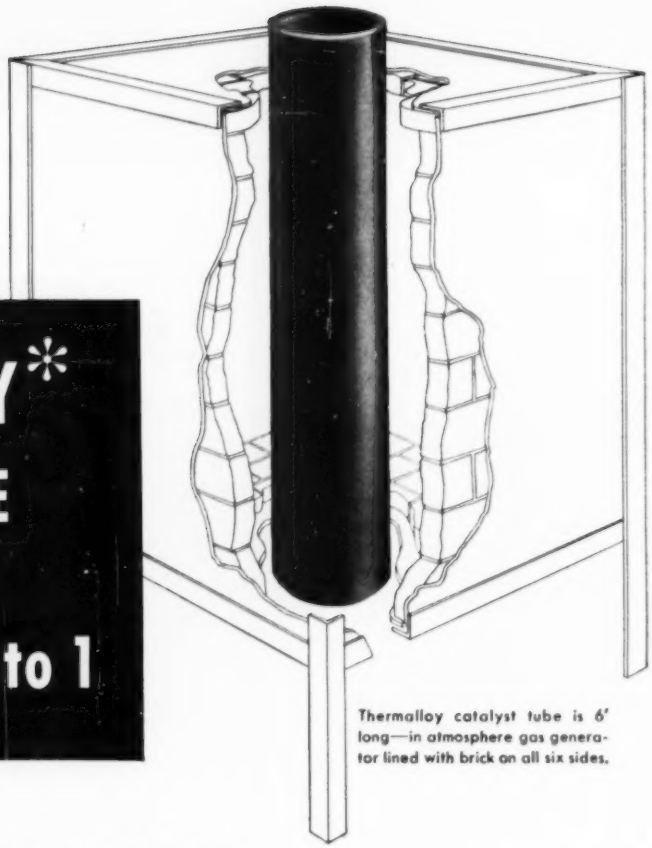
Digests of Important Articles

Sound Castings by Controlling Heat Transfer 126
Effect of Elevated Temperatures on Drawing Operations 130
Oxidation Resistant Copper Alloys 138
Advantages of Silicon Capping 142
Metallurgical Impasse in Welding Nodular Irons 174
Intergranular Brittleness 178
Basic Diagrams of Composition Vs. High-Temperature Strength . . 184
Properties of Aluminum Bearings 185
Quality Control in the Production of Copper and Its Alloys 186
Ultrasonic Equipment for Thickness Measurement 194
Advanced Technique for Making Precision Castings 196
Highly Sensitive Dilatometer 202
Ductility of Pure Chromium 208

Departments

The Atomic Age: President Eisenhower's Atomic Proposals 81
Light Metallurgy: The Rise and Fall of the Raines Law Sandwich, by Waldimir Anderson 84
Book Review: "New" Materials for High Temperature 86
Data Sheet: Equilibrium Between Steels and Dew Points of a Prepared Furnace Atmosphere, by Norbert K. Koebel . 96-B
Personals 116
Engineering Digest of New Products 13
Manufacturers' Literature 21
Advertisers' Index . . . . . Last page

THERMALLOY* CATALYST TUBE outlasts refractory tube 9 to 1



Thermalloy catalyst tube is 6' long—in atmosphere gas generator lined with brick on all six sides.

Another manufacturer is now realizing longer service and less maintenance with heat treating equipment . . . because a Thermalloy catalyst tube was used to replace the refractory tube in an atmosphere gas generator.

The Bowdil Co. of Canton, Ohio, a well-known maker of coal cutting equipment and commercial heat treater uses an atmosphere gas generator to crack natural gas to endothermic atmosphere in a catalyst tube that contains a nickel catalyst. The generator is gas-fired to 1850° F. outside the tube. Previously, a refractory tube was used . . . and *lasted only two months.* Then, Electro-Alloys cast a tube in high heat-resistant Thermalloy. *Installed over 18 months ago,* this Thermalloy catalyst tube is still in operation . . . giving this manufacturer more operating economy in heat treating.

Thermalloy is a group of tough heat-resistant alloys each developed to meet specific high-temperature operating conditions. In the modern foundry at Electro-Alloys, many types of high heat-resistant Thermalloy castings are produced for use as radiant tube assemblies, retorts, trays, fixtures, baskets, rollers. Call your nearest Electro-Alloys representative or write Electro-Alloys Division, 5002 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

Write for new Thermalloy Retorts and Muffles Bulletin T-239.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

As I was saying...

THE JOB of being president of A.S.M. has its compensating features, but it is a strenuous one. Requests for him to appear on National Officers' Night programs begin to reach Cleveland early in the spring, and a continuous flow of invitations reaches the president-elect's desk until the middle of August. Then all hands endeavor to work out a schedule which will permit attendance at as many chapters as possible with the least amount of travel; in any event he will cover 30,000 to 40,000 miles a year.

In the early days it was possible for a national officer to visit all chapters yearly, but with 86 chapters now it is impossible. This is to be regretted, but the officers and trustees assist in filling assignments and special engagements so that 40 to 50 chapters are visited each year.

In order that the chapters might have direct contact with the national office, the Society has developed regional group meetings at which the chairmen and vice-chairmen of all chapters in a specific region meet for a conference with the national secretary and a member from the national board once every two years; half the chapters are contacted in one year and the other half the following year.

For some 35 years I have made it a practice to visit chapters with the president whenever possible because he is always a person whom it is a pleasure to be with and a person of whom I am especially proud.

A delightful meeting occurred when I accompanied President Jim Austin on a visit to the Louisville Chapter. He received from the Secretary of State a certificate making him a Colonel on the staff of the Governor of Kentucky. This certificate gives him the right to be addressed as "Colonel", and also to attend the Governor's breakfast (for free) on the day of the Kentucky Derby.

I was glad to congratulate the president on his Colonelcy because I have just recently been made a Colonel on the staff of the Governor of Maryland, and if any of you would like to know what the Maryland Colonel said to the newly made Kentucky Colonel, it was merely this: "Let's have another cup of coffee."

The Secretary of State who presided at the ceremonies in Kentucky endeavored to instill into us a regard and esteem for the distilled products of his state. Said he, "The women of Kentucky are so beautiful the flowers droop their heads in shame, our horses are so swift that winged Mercury cannot keep up with them, and our bourbon is so delicious it is an honor to die a drunkard." He also explained the requirements for a Kentucky Colonel's breakfast — one quart of Kentucky bourbon, one pound of liver, one dog. The liver, he said, is for the dog.

Not to be outdone, the A.S.M. prexy gave his recipe for eggnog, which was received with thunderous applause: "Take a quart of bourbon (Kentucky bourbon, that is), and then all the eggs and milk you add to it make it that much worse."

I hope most of you read this column last month, stating that a call list will be established for those wishing to receive details of the technical program, study groups, plant visits, and costs, for the European Metallurgical Congress, June 1 to 19, 1955, in England, Germany and France. If you are interested, drop a note to the office and ask to be placed on the list, and information will be sent to you as rapidly as it develops. This trip will be an exceptional opportunity for you to visit England and the continent with your congenial friends and fellow-members and have the pleasure of exchanging ideas and confidences with your opposites abroad — the thrill of a lifetime!

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

P.S. I'll be seeing all of you in Boston, Hotel Statler, March 4 and 5, at the A.S.M. Midwinter Meeting. There will be a swell program.

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Removes more types of soil from more kinds of metals than is possible with other cleaning materials . . .

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The instrument that put electronics to work

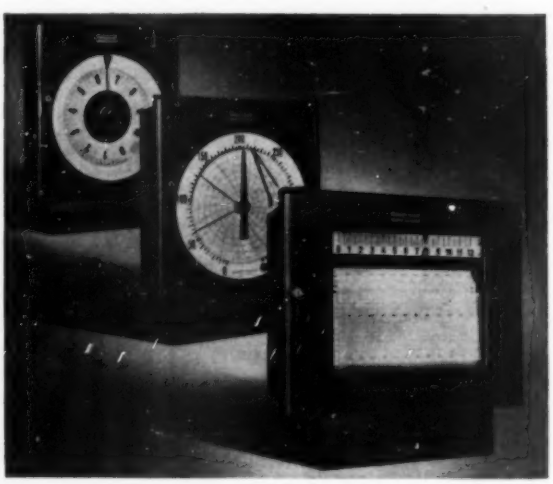
Before electronics came into the picture, industrial instrumentation was caught in a squeeze. On one hand, it was besieged with demands by production men and engineers for higher sensitivity, faster speeds, and greater reliability. And on the other hand, it was hampered by the limitations of mechanical devices. For the instruments of fourteen years ago were merely mechanical imitations of a man watching a galvanometer needle and twiddling dials. They were too delicate . . . too sensitive to vibration . . . too easily led astray by wear or maladjustment. They just couldn't deliver the performance that new production methods required.

In 1940, however, came a major milestone in the progress of instrumentation—Honeywell's development of the *ElectroniK* potentiometer. This was not only a new kind of instrument. It was a new concept of measurement. For the first time, it applied the science of electronics in a practical way to the design of a measuring device for industry. It replaced complicated, fragile mechanical gadgets with a simple but sensitive electronic circuit and servo system . . . the "Continuous Balance" principle of measurement.

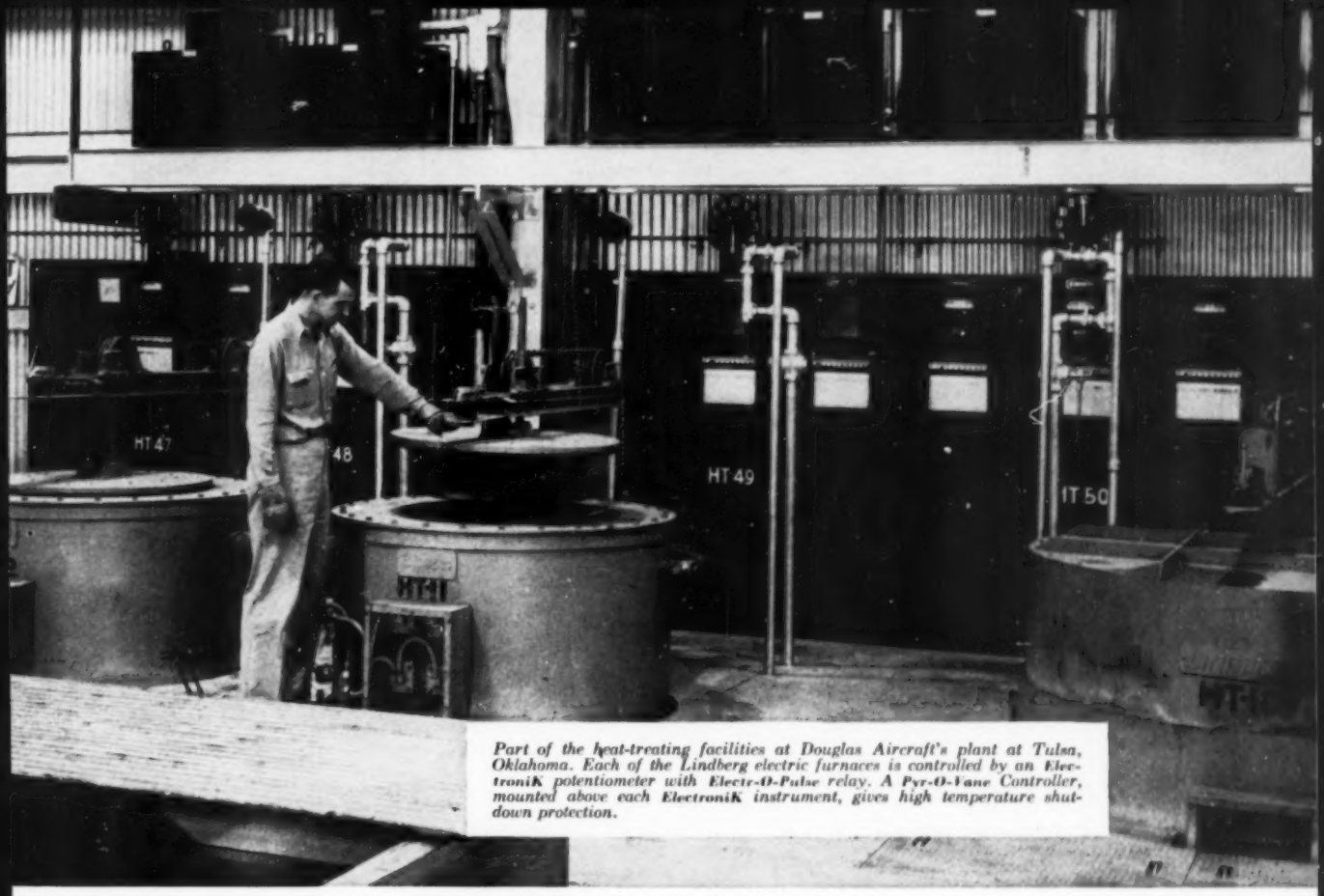
You could tell it was something new when you opened up the *ElectroniK's* case. There was no sign of whirring gears, levers and cams. You could tell it was giving a new kind of performance in measurement, too, by the way the pointer would move swiftly and surely in one smooth sweep whenever the measured variable changed.

The *ElectroniK* instrument gained quick acceptance by production men, engineers, research technicians and maintenance men. They liked the way it provided laboratory accuracy and sensitivity, week after week, under the toughest industrial service conditions. They found that its speed and precision made possible improvements in product quality and process operation that had been unattainable before. And they have proved their confidence by ordering and reordering *ElectroniK* instruments by the thousands . . . not solely because it was *first* of its kind, but because it has continued to be the *best* in performance.

Douglas Aircraft heat-treats to close specs in *ElectroniK*-



A variety of ElectroniK Controllers is available for regulating any type of furnace.



Part of the heat-treating facilities at Douglas Aircraft's plant at Tulsa, Oklahoma. Each of the Lindberg electric furnaces is controlled by an ElectroniK potentiometer with Electr-O-Pulse relay. A Pyr-O-Vane Controller, mounted above each ElectroniK instrument, gives high temperature shut-down protection.

controlled Lindberg furnaces

MEETING rigid military specifications on a mass-production basis is an every day job in Douglas Aircraft's heat-treating department. Tools and aircraft parts receive consistent, accurate hardening and tempering, through the use of Lindberg electric furnaces equipped with *ElectroniK* control.

To meet exacting requirements for temperature precision, required for varied treatment of low carbon to high speed steels, *Electr-O-Pulse* control was selected. This type of control provides proportioning action, by switching full heating power alternately on and off in impulses of variable length. And its automatic reset action keeps temperatures exactly at the specified value regardless of changes in furnace load, set point or line voltage.

● **REFERENCE DATA: Write for Catalog 1531, "*ElectroniK* Controllers".**

Whether your furnaces are large or small, batch or continuous, fuel-fired or electric, you'll get the best results from them through *ElectroniK* control. Your heat-treaters will like the way they hold temperatures to the closest tolerances for even the most critical operations. And your maintenance men will appreciate the simple, rugged design that keeps this instrument on the job week after week.

Your nearby Honeywell sales engineer will be glad to discuss control for your own furnaces . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Aves., Philadelphia 44, Pa.

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BROWN INSTRUMENTS
First in Controls

careful testing proved SUPERIORITY of

GULF LASUPAR

Mr. Raymond St. John, inspector, and a Gulf Sales Engineer discuss results with Gulf Lasupar Cutting Oil in machining bevel gears.

A close-up view of bevel gear cutting, showing Gulf Lasupar Cutting Oil in action.

CUTTING OIL

for every cutting operation at Belock Instrument Company, Long Island, New York

Belock wanted a cutting oil that would produce precision instrument parts to extremely close tolerances, and give an excellent surface finish with as few tool changes as possible.

After careful tests, using many kinds of cutting fluids, they found that Gulf Lasupar Cutting Oil gives them better performance over their entire range of machining operations on the many types of steel they process.

In Gulf Lasupar Cutting Oil you get three degrees of sulphur activity, each designed to provide better protection for the tool and to insure a better finish under a given set of machining conditions—(1) extremely active free sulphur held in a stable solution, (2) sulphur combined with mineral oil by a special Gulf process, and (3) sulphur combined with fatty oil.

A Gulf Sales Engineer will be glad to demonstrate the advantages of Gulf Lasupar Cutting Oil in your plant. You will find him always "on call" at your nearest Gulf office.

A Bechler Swiss Automatic Screw Machine Cutting A.I.S.I. 416 Stainless Steel. These Gear Blanks are held to tolerances of .0003 of an inch.

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Junior Achievement Week
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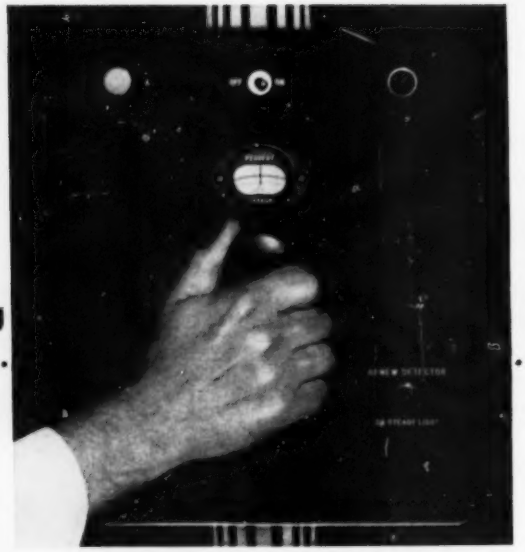
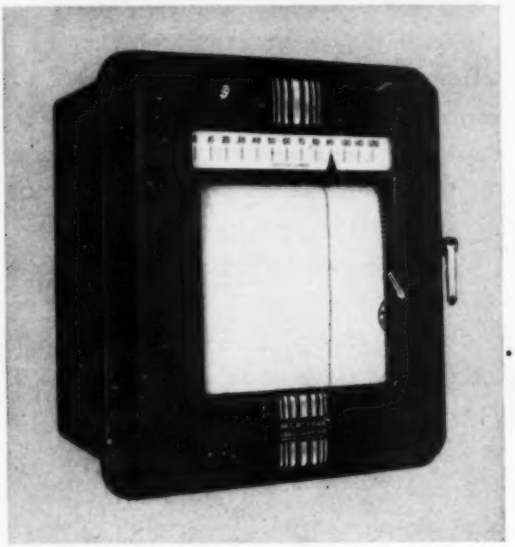
THE CARBON YOU ..... set .....



IS THE CARBON YOU ..... get .....



. . . with MICROCARB® ATMOSPHERE CONTROL

With a twist of the dial . . . Microcarb Atmosphere Control automatically regulates and continuously records the active carbon in a furnace atmosphere during the heat treating cycle.

For this reason the Homocarb method with Microcarb is a basic advance in heat treating.

Whether specifications demand case carburizing, hardening, homogeneous carburizing or carbon restoration . . . "the carbon you set is the carbon you get".

You simply dial the carbon you want. From then on the Microcarb Controller directly measures and controls the active carbon in the atmosphere surrounding the work. At the same time the Carbon Recorder draws a continuous record of percent carbon.

For complete information on the Homocarb method with Microcarb Atmosphere Control just write Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Penna.

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instruments automatic controls • furnaces

Jrl. Ad T-620(45)

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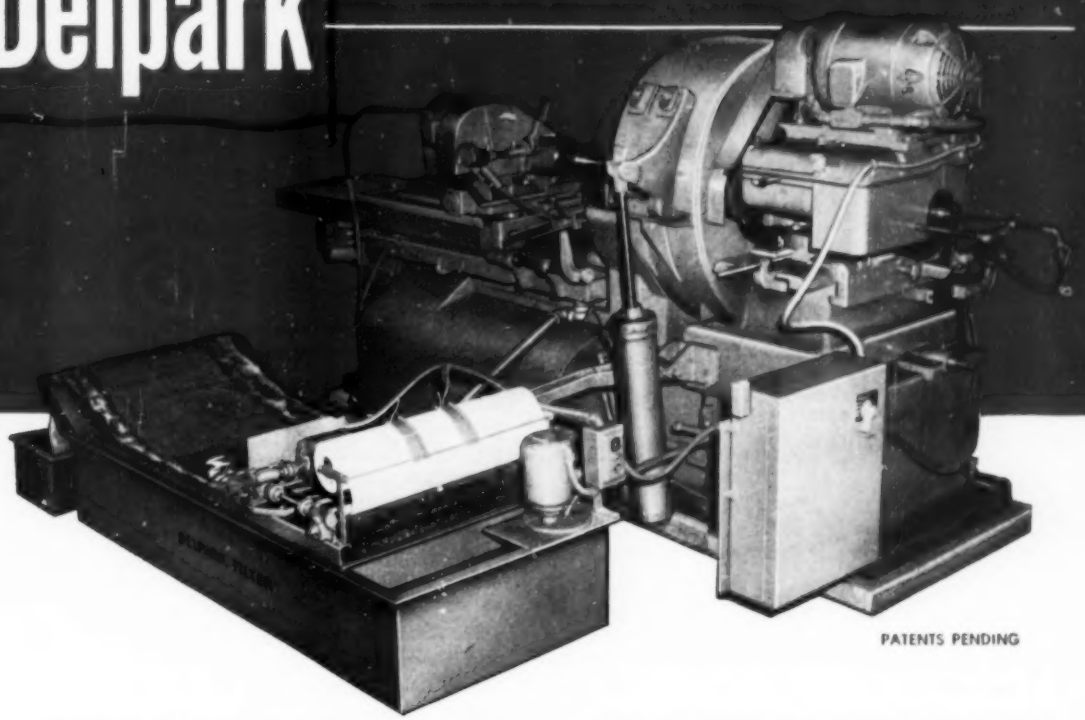
SAYS WILLYS MOTORS, INC.
TOLEDO, OHIO
OF

Delpark INDUSTRIAL FILTRATION



PATENTS PENDING

The DELPARK Story runs true to form at *Willys Motors, Inc.* Here, where a number of DELPARK Filters are in service 16 hours a day, they operate with little attention at a minimum of cost.

Willys Motors says, "We never have to change the coolant, or clean the tank, excepting perhaps on a six month basis, to remove contaminants from floor sweepings. Time spent in cleaning tanks with conventional equipment would many times pay for the filter equipment."

There is one other point to remember: that DELPARK Filters make possible the full capabilities of fine precision grinders which otherwise would be impossible. Greater machine efficiency and fewer rejects add even more to the enormous savings made possible with DELPARK Filters.

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INDUSTRIAL FILTRATION COMPANY
116 Industrial Avenue, Lebanon, Indiana

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~new low-carbon ferrochromium...

exceptionally clean, dense, low in carbon

EXLO

is produced in a completely new plant which Vanadium Corporation has recently added to its existing facilities at Graham, West Virginia.

EXLO, a unique, new extra low-carbon ferro-chromium containing .025% carbon maximum, is distinguished by the following properties:

HIGH DENSITY—apparent density is very close to true density; less storage space is required per unit of chromium.

EXCEPTIONAL CLEANLINESS—eliminates many undesirable nonmetallics which might be added to the metal.

HIGH CHROMIUM-CARBON RATIO—results in less objectionable carbon being added per unit of chromium.

HIGH CHROMIUM CONTENT—reduces the total ferro alloy needed in late furnace additions to meet the chromium specifications of the steel.

LOW SILICON CONTENT—to meet the specific needs of the individual steelmaker.

. . . *and* EXLO can be furnished in a wide range of sizes.

These unique advantages point to scores of important applications. With EXLO, the steelmaker can now produce top-quality stainless steels of extremely low carbon content.

EXLO is a product completely new to the iron and steel industry of America. It is the result of a unique, exclusive process . . . a process adopted as part of Vanadium Corporation's long-range program designed to meet the growing demand for more and better alloys throughout the metals industries.

Your nearest Vanadium Corporation representative will be glad to give you further information on EXLO and its applications. Call or write him today.

EXLO is also available in .06% carbon maximum grade. For some steel specifications, use of this alloy eliminates the need of blending chromium products of higher and lower carbon content.

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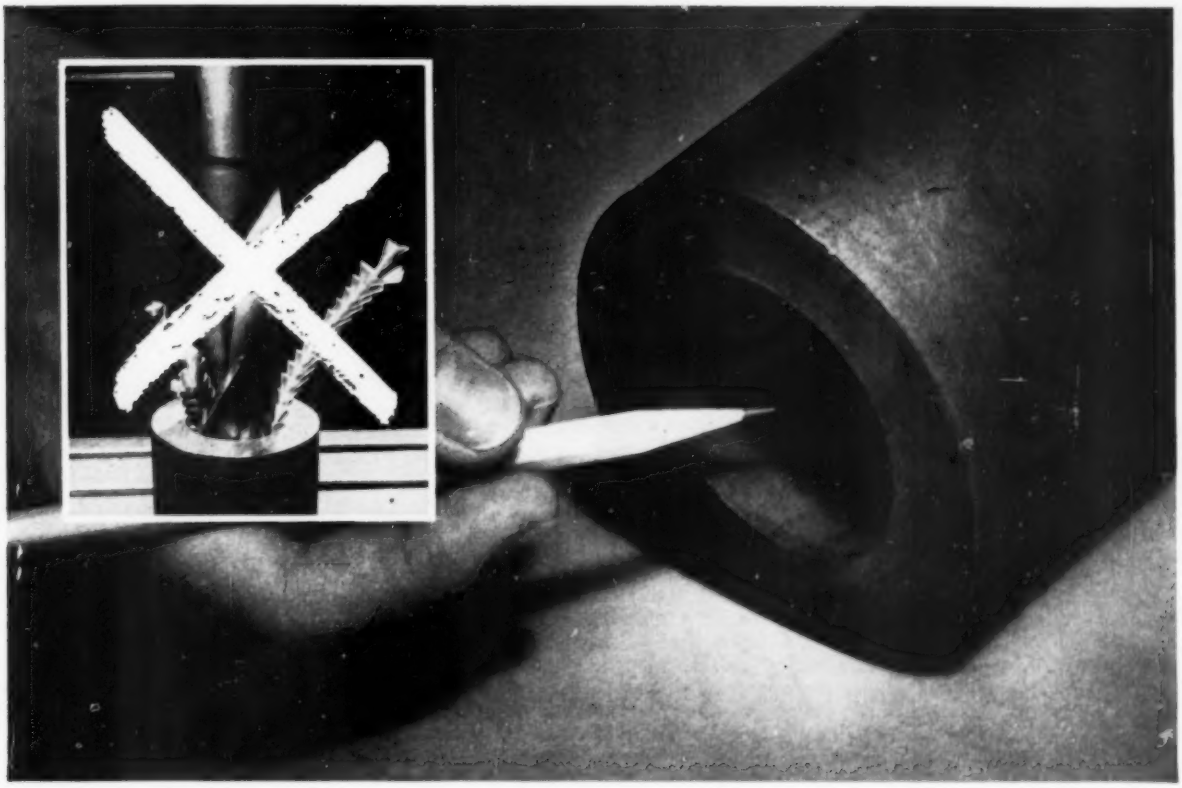


Eliminate drilling! Finish boring's the first step with TIMKEN® seamless steel tubing!

DRILLING'S a thing of the past when you use Timken® seamless steel tubing. The hole's already there! You save time and money by starting with finish boring.

Screw machine stations are available for other jobs. The result: You add machine capacity without adding machines.

Timken seamless steel tubing saves you additional money because you don't waste steel. All you pay for is the steel you use. We give you the holes.

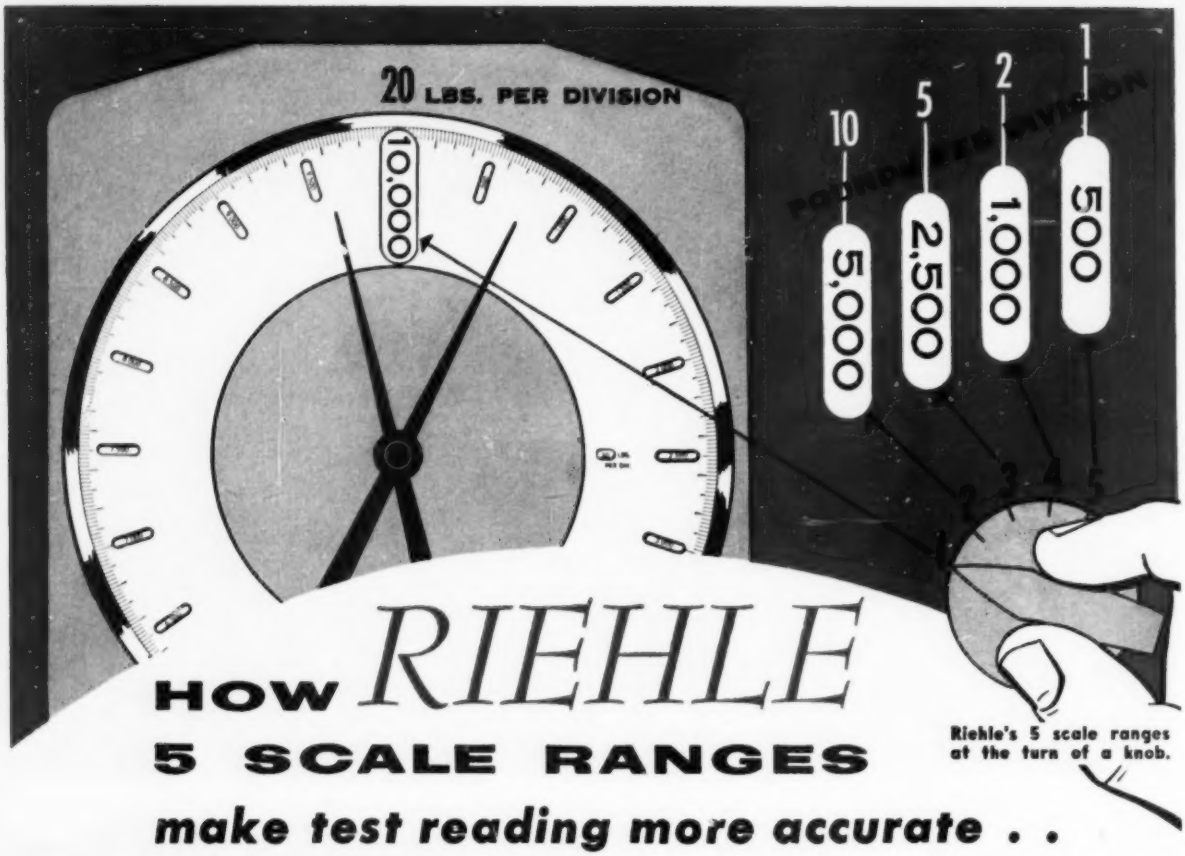
To make sure you get the most steel per dollar, our engineers will be glad to study your problem and recommend the most economical tube size for your hollow parts jobs.

Timken seamless steel tubing gives you high internal quality because the piercing process by which it's made is basically a forging process. It has a uniform spiral grain flow for greater strength, and a refined grain structure which brings out the best in the quality of the metal. And our rigid quality control makes sure that the quality is uniform from tube to tube and heat to heat. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

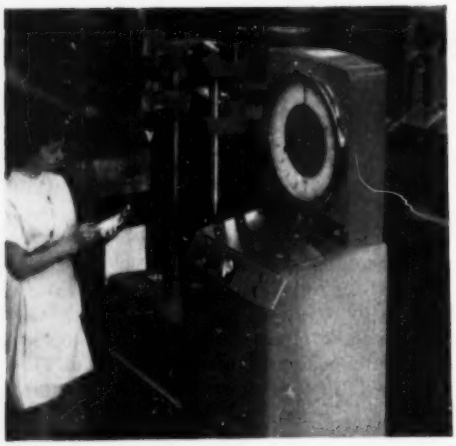
TIMKEN
Fine Alloy
STEEL

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING



HOW RIEHLE 5 SCALE RANGES make test reading more accurate . .

Riehle's 5 scale ranges at the turn of a knob.



There's no chance for mis-reading when you're using a Riehle Pendomatic Universal Testing Machine.

On beginning a test, the operator sets Riehle's selector knob to the logical scale range. Automatically the corresponding pound load figures appear on the indicator dial. Riehle's 5-range system allows most exact interpolation by providing the fewest number of pounds per dial division. For example, when using range 5 on a 10,000 pound Riehle Pendomatic Universal, each division represents only 1 pound. This feature assures greater accuracy in reading. Also it lessens the chance for error if the operator happens to read the dial from a slight angle.

This 5 scale range dial is a *standard feature at no extra cost,* on all Riehle Pendomatic Universal Testing Machines.

Accurate to ½%, a Riehle Tester is mechanically simple, rugged and foolproof.

Riehle Universal Testing Machines are built with hydraulic or screw power loading unit. Each type is available in capacities up through 400,000 pounds. Use handy coupon to request catalogs.

Low loading table and gripping head make it easy to place specimens in a Riehle Universal Testing Machine. Its streamlined design enhances the appearance of modern testing laboratories.

- **RIEHLE TESTING MACHINES**
- **Division of American Machine and Metals, Inc.**
- **Dept. MP-254, East Moline, Illinois**

☐ Please send catalogs on Riehle Testers
☐ Send name of Riehle representative

COMPANY

ADDRESS

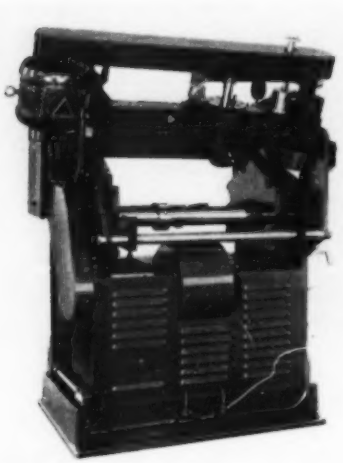
CITY ZONE STATE

NAME AND TITLE

engineering digest OF NEW PRODUCTS

Semi-Automatic Brinell

A new semi-automatic Brinell testing machine has been announced by the Detroit Testing Machine Co. With this machine, testing operations will require only half the previous labor



force, as it automatically indexes test pieces through both spot grinding and Brinell testing stations. At the rate of 400 pieces per hour, crankshafts, gun barrels, or other shaft-like parts, are fed into the machine. Now being successfully used to test crankshafts, the manufacturer offers modifications to suit customer specifications.

For further information circle No. 305 on literature request card on p. 32-B.

Bright Nickel

Unichrome bright nickel process has now been made generally available to the plating industry. The process, which was developed in the United Chromium laboratories, has been field proved in commercial operations. High solubility is a characteristic of the addition agents. In many installations this bright nickel has helped solve problems connected with low brightener solubility. It has, for example, minimized problems of brightener drying out on the work and brightener crystallizing on tanks and equipment after cooling of the plating solution. This solubility and the use of all-liquid addition agents have made maintenance easier. Unichrome bright nickel provides a superior base for chromium plating. Exhibiting excellent receptivity for chromium deposits, it has significantly reduced "gray plate rejects" in numerous installations. The solution has a nickel sulphate, nickel chloride, boric acid composition with addition agents.

For further information circle No. 306 on literature request card on p. 32-B.

Spring Alloy

Elgiloy, the cobalt-base spring alloy developed by Elgin National Watch Co., is again available for general use. Composed principally of cobalt (40%), chromium (20%) and nickel (15%), the alloy first achieved success as a watch-spring material. Other uses are for pen nibs, toaster pop-up mechanisms, flapper valves, surgical and dental equipment, drawing instruments, camera parts, wrist-watch bands and snap-switch components as well as in countless forms as springs.

For further information circle No. 307 on literature request card on p. 32-B.

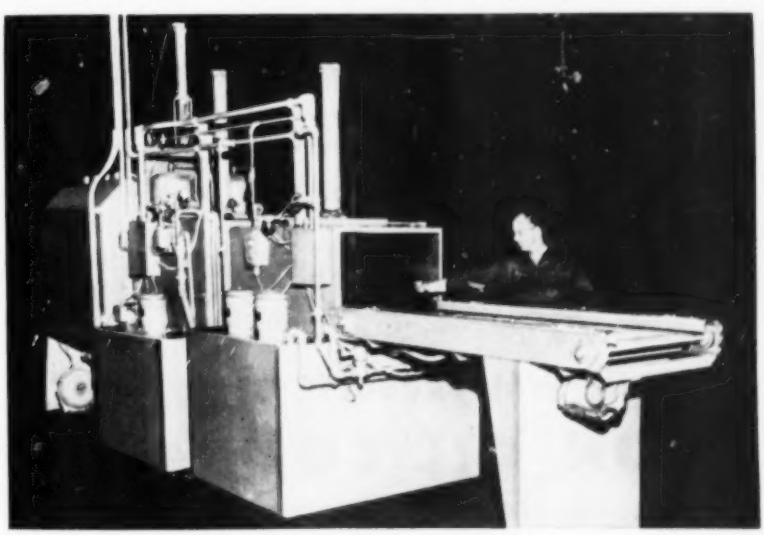
X-Ray Processing

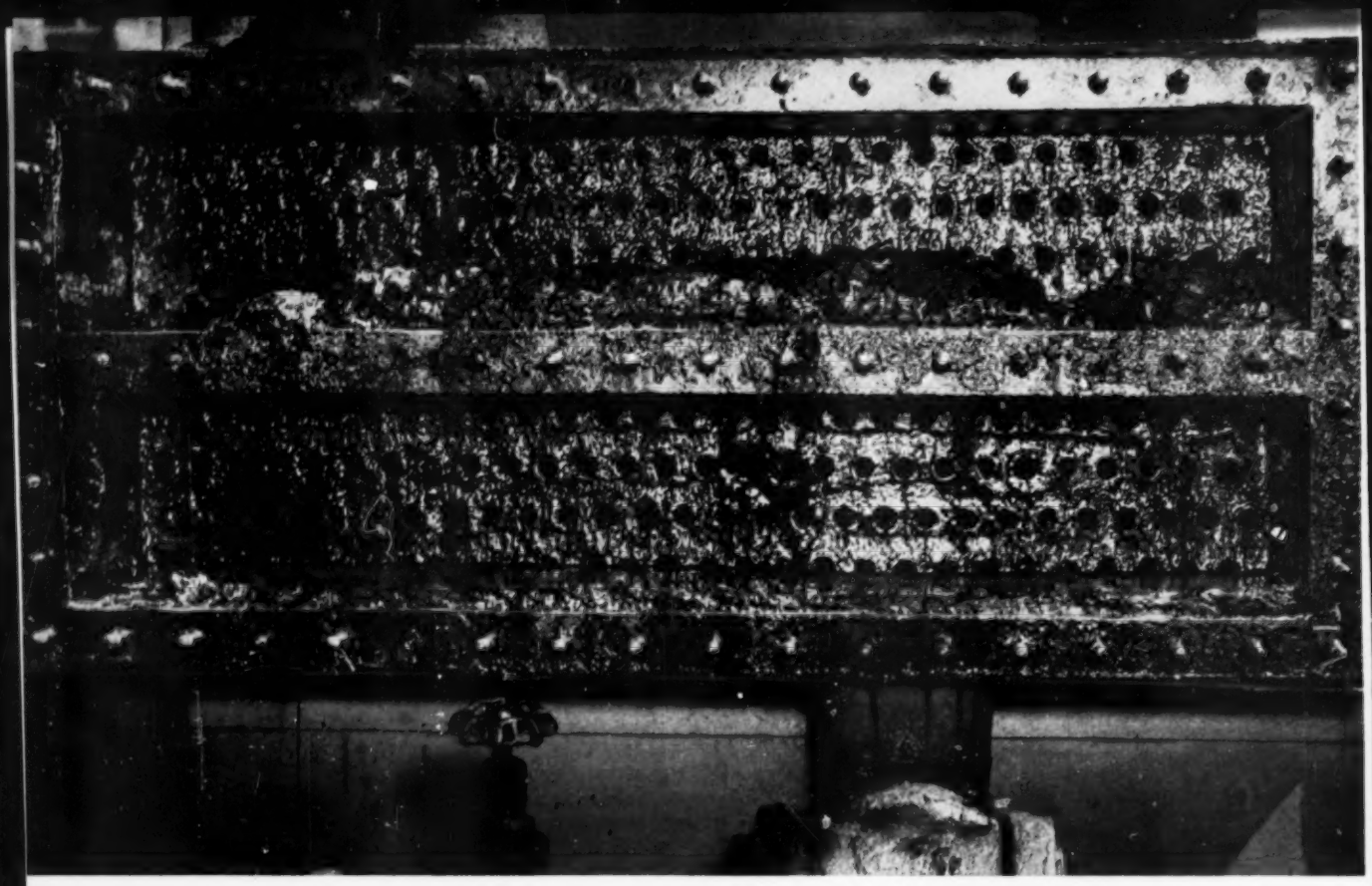
A 50% decrease in X-ray film processing time has been achieved through the use of a new liquid chemical announced by the X-Ray Dept. of General Electric Co. Named fixer-neutralizer because it is used following the fixing process so that films do not become overfixed, it preserves films so that they may be kept many years without danger of staining. While it is necessary to put films in fixer-neutralizer for 5 min., this action decreases the necessary washing time to 5 min. rather than the former 30 or 40, so the overall saving in processing time is a minimum of 20 min.

Quench Unit

A new brine quench unit, designed to speed quenching of heat treated metals through automatic cycling, has been announced by Ipsen Industries, Inc. The self-contained unit features completely automatic transfer of work load from adjoining heat treating furnace through its own brine quench and has been developed for use with Ipsen series-T furnaces. Solution temperatures, work handling and solution circulation are all controlled automatically by presettings of controls built into the regular furnace control panel. Temperature of the brine solution is controlled by immersion-type, finned cooling coils through which tap water passes. A Partlow temperature control unit assures proper uniform temperature of the solution. The loader section of the unit also serves as a roller-type unloading platform.

For further information circle No. 308 on literature request card on p. 32-B.





If you use an ordinary quenching oil that forms sludge deposits, here's what can happen to your oil cooler.

SUN QUENCHING OIL LIGHT WON'T CLOG COOLERS

Sludge lowers operating efficiency, ups maintenance costs, cuts output. Sun Quenching Oil Light, when used at normal temperatures, keeps coolers clean, because it has a natural detergent action that prevents the formation of sludge deposits and aids in removing any deposits that have accumulated. And this oil thins out when heated—reduces drag-out, brings operating costs down. The booklet "Sun Quenching Oils" tells the story of Sun's money-saving quenching oils. Call a Sun office or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-2.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

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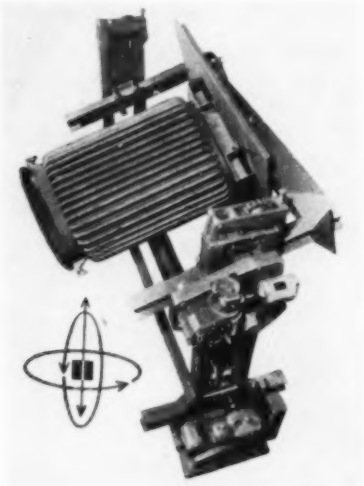
Because films are not saturated with either fixer or water, the drying time is also decreased.

For further information circle No. 309 on literature request card on p. 32-B.

Weldment Positioner

A new positioner offering three degrees of freedom for efficient downhand welding has been developed by Pandjiris Weldment Co. The positioner provides for horizontal table rotation of 360°, vertical rotation of



360°, and elevation to move the weld-job up or down. All positioning is done by pressing a button. The table can be set in a low position for loading the weld-job upright. Capacities range from 500 to 20,000 lb.

For further information circle No. 310 on literature request card on p. 32-B.

Stiffness Tester

Now available is the Taber Model 150 stiffness tester for determining both initial and basic stiffness of sheet and wire specimens. The new model is more sensitive than previous models, having eight test ranges instead of six. Flexural rigidity of very thin materials such as metal foil and watch springs can now be determined with an attachment which magnifies dial readings 100 times. Test length, angle of deflection and rate of loading are all standardized for accurate test results among different laboratories. Readings are taken direct from dial, making reference charts, tables and lengthy calculations unnecessary. A triple-cut shear blanks out precision specimens, eliminating variations in results caused by using specimens of different sizes.

For further information circle No. 311 on literature request card on p. 32-B.

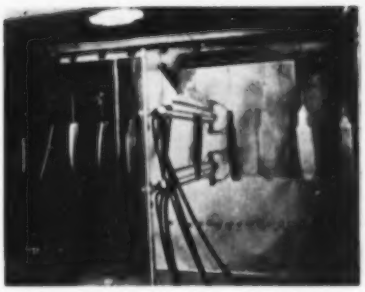
Box-Type Furnace

A new box-type electric heat treating furnace has been announced by K. H. Huppert Co. This new series is built in five different sizes, from 6 in. wide 6 in. high 9 in. deep, to 10 in. wide 8 in. high 18 in. deep. The furnace is designed with a new skirt type cabinet, and is furnished complete with transformer, contactors, switch box, and electric indicating temperature controller.

For further information circle No. 312 on literature request card on p. 32-B.

Electrostatic Paint Spraying

The Scientific Electric high-potential paint spraying equipment demonstrated at the National Metal Exposition in Cleveland, is designed for use with lacquers, enamels, synthetics, varnishes, plasticols, teflon and other alkali paints. The spray apparatus itself charges the coating, with the effect of producing better coverage of paint at substantial savings in wasted vehicle over conventional methods.



For further information circle No. 313 on literature request card on p. 32-B.

Decarb Test

A new and extremely simple test for determining the neutrality of a neutral salt bath furnace has been announced by Ajax Electric Co. This test, which requires only a discarded razor blade, has been checked and used successfully by a number of salt bath furnace users. The razor blade test requires only immersion of a blade in the molten bath for the prescribed time of 10 or more minutes at a given temperature, followed by a quick water quench. Because of the thinness of the blade, this test is ex-

This special purpose A-F Washing Machine was built for one of the nation's largest automobile plants to remove grease and chips from rocker arm shafts after the machining operation.

A unique feature is the special type of A-F Bar Conveyor unit which provides maximum washing and drying area.

For a discussion of latest metal parts cleaning methods, write today.

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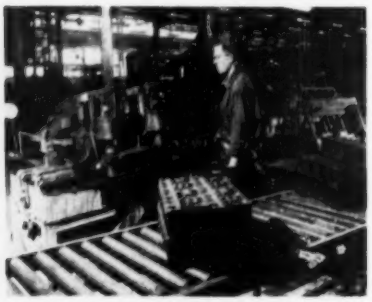
tremely sensitive to an oxidizing bath. Partial or complete decarburization can be determined by the ductility of the quenched blade. If the blade bends, then carbon has been depleted, and the salt bath showing this evidence of a decarburizing tendency should be rectified immediately. However, if the blade snaps, the bath is neutral.

For further information circle No. 314 on literature request card on p. 32-B.

Castings Sealant

Tincher Products Co. has announced details of a production use of the company's metallic seal and equipment. Three sizes of engine head



castings running 20% leakers are sealed, salvaging up to 96% of the defectives. 130-lb. castings are sealed at 6 to 8 per hr.; 80-lb. castings at 10 per hr.; and 55-lb. castings at 25 per hr. Heated seal solution is circulated through the casting to heat it to 180° F.; 400 psi. is applied for 5 min., casting drained and cured for 8 to 24 hr.

For further information circle No. 315 on literature request card on p. 32-B.

Magnet Material

A completely new type of magnet, composed of ceramic material which is lighter than metal and requires no critical ingredients, has been announced by the Indiana Steel Products Co. The new permanent magnet, called Indox, is magnetized in the same manner as metals, but the magnitude of the magnetizing force required is more than three times that necessary for Alnico. In addition to being lighter than Alnico, and requiring no critical materials, Indox has twice as much coercive force as Alnico and is a nonconductor. It is virtually impossible to demagnetize the material by any ordinary means. Indox is made from iron oxide and barium carbonate, and goes through a number of critical cycles in powder preparation, pressing in dies, and heat treatment. Initially it will be manufactured for use in television focus rings, novelties, toys, and holding devices. Indox has a coercive force of approximately 1600 oersteds and an intrinsic coercive force of approximately 4000 oersteds. It can withstand demagnetizing fields above 2000 oersteds without large loss of magnetic flux. It is characterized by short magnetic lengths, with an optimum working point of approximately 1000 gauss at 800 oersteds. Indox loud speaker magnets have about half the magnetic length of Alnico magnets.

For further information circle No. 316 on literature request card on p. 32-B.

Metal Sprayers

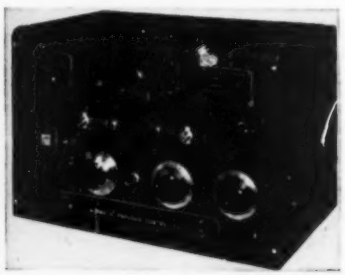
The Forrester Co. has made available two new low-temperature alloy metallizers, designed for close tem-

perature and spray texture control. The units incorporate temperature controlled, electrically heated integral crucibles, one unit of 4 and the other of 12 cu. in. capacity.

For further information circle No. 317 on literature request card on p. 32-B.

Electronic Controllers

Development of automatic testing program controllers has been announced by the Tinius Olsen Testing



Machine Co., for automatic production and quality control testing as well as research programs. Units are available for any one or any combination of automatic testing controls. Illustration shows composite unit which incorporates all testing controls.

For further information circle No. 318 on literature request card on p. 32-B.

Buffing Lathe

Hammond Machinery Builders, Inc., have announced a new 10-hp. wide-swing variable-speed polishing and

HIGH AND LOW TEMPERATURES

NEW BENCH-TYPE TEST UNIT

WEBBER

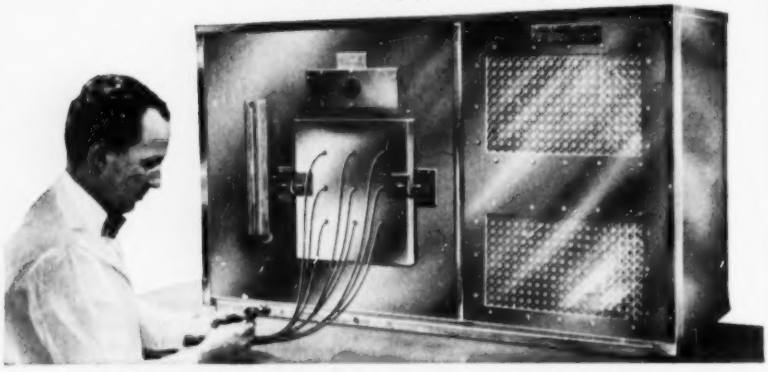
TRADE MARK REGISTERED

COMPLETE TEMPERATURE RANGE

TESTING UNITS

Combine high and low temperatures within the same cabinet with all controls self contained. Unit measures 50"x28"x20" with a testing chamber 12"x12"x12". Temperature range is from -80° F., to 185° F. Heat application is accomplished with reverse cycle refrigeration, which eliminates the hazards associated with open heating elements. A blower is provided for even distribution of temperatures and greater testing accuracy. Latch-type or hinge-type door optional. Accelerated pull-down to -80° in 30 minutes or less.

Write today for more complete information



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New facts for your file on U·S·S CARILLOY STEELS

Special non-magnetic U·S·S Carilloy steel anchors Navy's newest minesweeper

● The United States Navy has made minesweeping operations more effective with the help of U·S·S Carilloy steel.

During World War II, a new weapon in marine warfare was developed —the magnetic mine. These mines explode when an ordinary steel ship comes near. To sweep such mines safely, without premature or uncontrolled explosions, the Navy is building a fleet of radically new *non-magnetic* minesweepers.

Finding a suitable steel for the anchor chains on these ships was quite a problem. The chains scrape over hard rocks, sand, and coral along the ocean floor, so they must have good resistance to abrasion. In addition, they must withstand heavy tension, torsion, and impact stresses as wind and tide pound at the ship. To top it off, they must be non-magnetic.

The Navy satisfied *all* these tough requirements with Carilloy austenitic manganese steel. Intimate knowledge of steels and accurate, skillful control of each step in steel making enabled us to meet the unusual specifications.

Experience on extraordinary jobs like this helps us to do a better job on your steel, whether you need a standard AISI grade or a special analysis. When you need high-quality alloy steel, specify U·S·S Carilloy. And when you need expert metallurgical advice, get in touch with the nearest U·S·S District Sales Office.

NON-MAGNETIC ANCHOR chains are forged from U·S·S Carilloy austenitic manganese steel. They are cooled after forging.

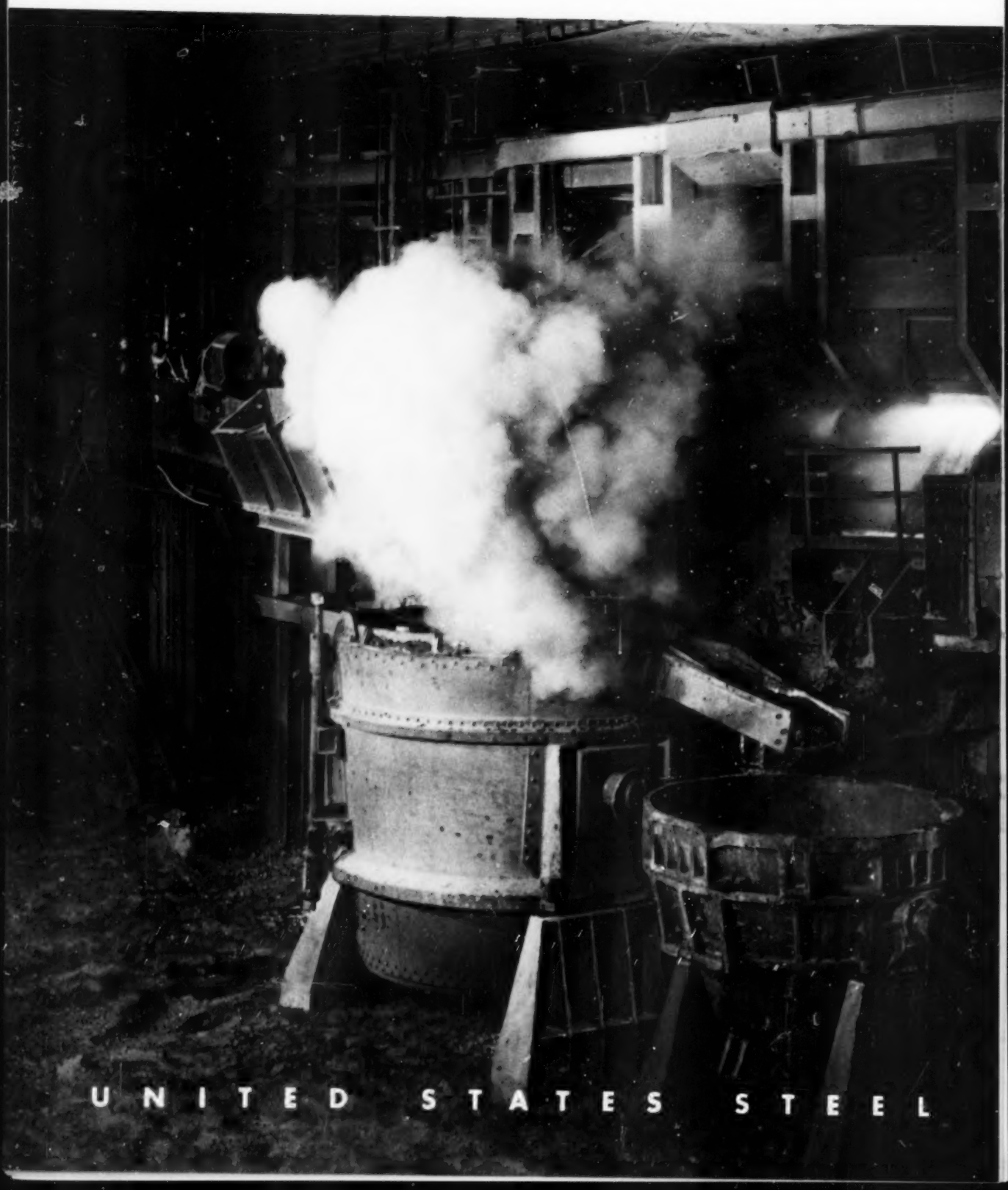
LENGTH of this ¾"anchor chain is checked after proof test loading at Boston Naval Shipyard. Ductility is extremely important in these chains, and the U·S·S Carilloy steel provides elongation of 80%.

USS

UNITED STATES STEEL CORPORATION, PITTSBURGH · COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. · UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

"Our forgings really



y start with a bang!"

says Vincent Czaplinski

U. S. STEEL SENIOR MELTER FOREMAN

● First you are warned with a shrieking whistle. Then with a roar, an explosive blast pierces the plug that seals the open hearth tap hole. When the smoke lifts, you finally see the bright stream of molten steel shoot from the bottom of the furnace to fill the 230-ton ladle.

This is probably the most dramatic single operation in the making of steel forgings. It's the beginning of many U·S·S Quality Forgings—giant carbon steel water wheel shafts, massive anvil bases for drop hammers, high alloy turbine rotors and ship propulsion shafting.

Vincent Czaplinski came to the open hearth right out of school. For 23 years, he worked up through 3rd, 2nd and 1st helper—doing everything from cleaning out tap holes to building new furnace bottoms. Today, as Melter Foreman in charge of 5 furnaces, it is his job to hit the analysis right so that the forging you get is the finest that can be made. Relatively few men in the country know as much about actually making steel as Vincent Czaplinski, and he is typical of the men who produce the quality steel that goes into every U·S·S Quality Forging.

Write for our free 32-page booklet that describes the men, the steel and the equipment that go into U·S·S Quality Forgings. Write to United States Steel, 525 William Penn Place, Room 4227, Pittsburgh 30, Pa.

USS Quality FORGINGS

heavy machinery parts—carbon alloy, stainless

drop hammer bases and columns

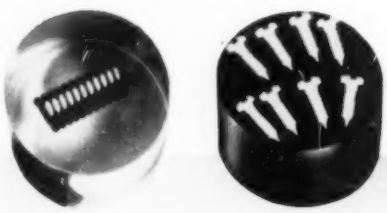
electrical and water wheel shafts

forged steel rolls and back-up roll sleeves

NEW BUEHLER CATALOG

200 pages — a comprehensive catalogue of Buehler equipment for the metallurgical laboratory. Includes sections on Cutters, Grinders, Specimen Mount Presses, Polishers, Metallographs, Microscopes, Cameras, Testing Machines, Spectrographs, Furnaces and other equipment for the metallurgical laboratory.

Buehler Ltd.



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The answer to most of your questions about stainless steels are right at your finger tips, when you use Crucible's unique new Stainless Steel Selector.

Want to know the machinability characteristics of a stainless grade? Resistance to corrosion or scaling? Physical or mechanical properties? You can get the answers to these and other questions simply by setting the arrow on the Selector slide at the proper window. It's just as quick and easy as that.

And almost as fast as you get the answer, you can get the steel you need. For many of the REZISTAL stainless steels shown on the Selector are carried in stock in Crucible warehouses conveniently located throughout the country.

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HOW THE SELECTOR WORKS:

Start with the problem. For example, resistance to corrosion in contact with copper sulfate. Just set the slide at the proper index number shown on the Selector (in this case on the back), and you have the answer in a second – grades 302 and 316 are fully resistant to this form of attack.

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54 years of Fine steelmaking

STAINLESS STEELS

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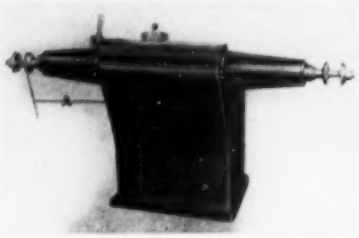
buffing lathe, as illustrated. This new lathe has extended spindle affording maximum working area around the wheels and has a variable spindle

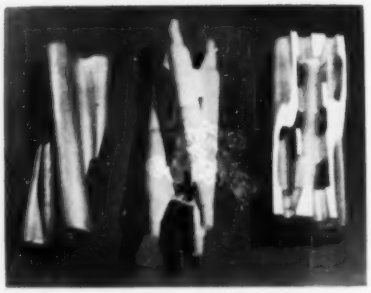


speed range of 1500 to 3000 rpm. Speed is instantly changed by dial control while the machine is running.

For further information circle No. 319 on literature request card on p. 32-B.

Precision Foundry Cores

Precision sand cores made with Bakelite phenolic resins cut production cost of aluminum castings and the time required in machining. Cores produced by this method are baked in the core box to the desired strength and rigidity in a few minutes. This eliminates the expense of a large number of accurate core driers, required to produce conventional cores. These cores must also withstand the

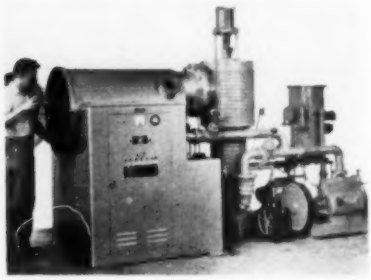


pressure and heat of molten aluminum at 1425° F. long enough to shape accurately the interior of the casting. Since the finished casting shown above must be balanced, the more accurate cores save machining of the interior after all outside surfaces have been finished. (Casting and core shown above are by Maco Corp.)

For further information circle No. 320 on literature request card on p. 32-B.

Vacuum Coating Unit

A new vacuum coating unit for the smaller runs is now available from Consolidated Vacuum Corp. The unit has a normal production rate of four cycles per hour; with base materials of low volatile content five cycles an hour may be attained. Designated as Type LC1-30, the new model has a 30-in. diameter horizontal chamber mounted on a steel cabinet which contains the filament power supply, the fixture-rotating motor and a door-mounted electrical control panel which opens to facilitate maintenance. The pumping system includes a high



speed 14-in. oil diffusion pump, a small mechanical holding pump and a 100 cfm. mechanical pump for roughing and backing.

For further information circle No. 321 on literature request card on p. 32-B.

Electron Microscope

A new electron microscope is now available from North American Philips Co., Inc. The new instrument utilizes an electron-optical system that includes condenser, objective and projector lenses. Magnification is continuously adjustable between 1500 and 15,000 diameters. Resolving power is better than 100 Angstroms under average operating conditions. The new unit has a magnetic stabilizer. The electron gun is self-biased and is equipped with an emission meter. Diameter of the fluorescent screen is 4⅝ in. and diameter of images 3⅛ in. A camera using 35-mm. standard film is employed and permits exposures without breaking the vacuum. The electron microscope is approximately 74 in. high, 37 in. wide, and 25 in. deep. Power supply is 220 volt, 50 or 60 cycles and power consumption is about 1 kw.

For further information circle No. 322 on literature request card on p. 32-B.

Batch Heat Treating

Cooley Electric Mfg. Corp. is offering its recirculating air draw furnaces with chamber sizes of 8 x 6 x 14 in. and 12 x 8 x 8 in. for tempering steel and other operations requiring precise low temperature control. These are said to be particularly useful in the precise heat treating of

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Pyrometers with the above features are available for all industrial applications. This complete line of instruments handles any temperature control problem . . . **On-Off Controllers, High Limit, Proportioning, Three Position, Program, Portable Temperature and Stepless Controllers.** Write for detailed bulletins.

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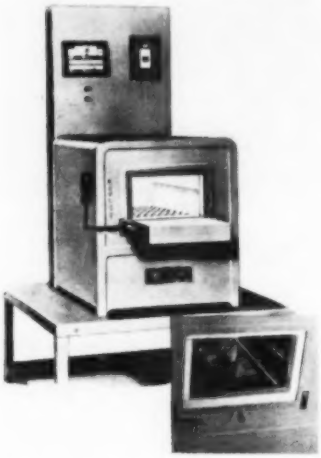
rivets. This small furnace follows the design and performance characteristics of large convection type fur-



naces. It has an integral factory wired control panel, insuring correct and simple installation.

For further information circle No. 323 on literature request card on p. 32-B.

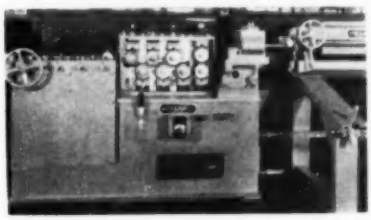
Sub-Zero Unit

A new low-temperature machine for production chilling of ball and roller bearings for stabilization has been announced by Sub-Zero Products Co. This unit is adjusted to operate at −120° F., and can be operated as cold as −150° F. It has a capacity of 22 cu.ft. and a thermal capacity of 4000 Btu. per hr. The chamber of the unit is filled with a convection fluid, Freon 11. A twin-blade agitator mounted in the corner of the chamber drives the fluid down a draft tube, through a manifold and up through the basket of parts. This forced flow permits cooling of 170 lb. of steel an hour from +80° to −120° F.

For further information circle No. 324 on literature request card on p. 32-B.

Wire Straightener

Details of a new shaped wire straightener and cutoff machine have been released by the Medart Co. It



incorporates a number of exclusive design features, including infinitely variable all-hydraulic drive, adjustable from 100 ft. per min. to 225 ft. per min. The hydraulic drive features instant starting and stopping and from full speed forward to full speed reverse instantaneously, allowing the machine to be set up rapidly at a great saving of wire. The hydraulic shear is actuated by an electric device which can be set for a predetermined length of cut. The machine is rated to deliver a finished 12-ft. long piece of wire from coil every 3¼ sec.

For further information circle No. 325 on literature request card on p. 32-B.

Corrosion Resistance

The Atlas Mineral Products Co. has announced Vitroplast, a new vinyl base chemical resistant cement which is completely resistant to hydrochloric acid, phosphoric acid, 60% sulphuric acid, 5% nitric acid, 5% chromic acid, sodium hypochlorite, benzene, gasoline, and chlorine dioxide at temperatures up to 150° F. Unlike standard chemical resistant resin cement, the new cement does not require acid or alkaline setting agents and will set in contact with concrete or steel and under adverse conditions. It has a working time of approximately 40 min. and a setting time of less than 2 hr. at ordinary temperatures.

For further information circle No. 326 on literature request card on p. 32-B.

DURIMET
MICRO-HARDNESS TESTER

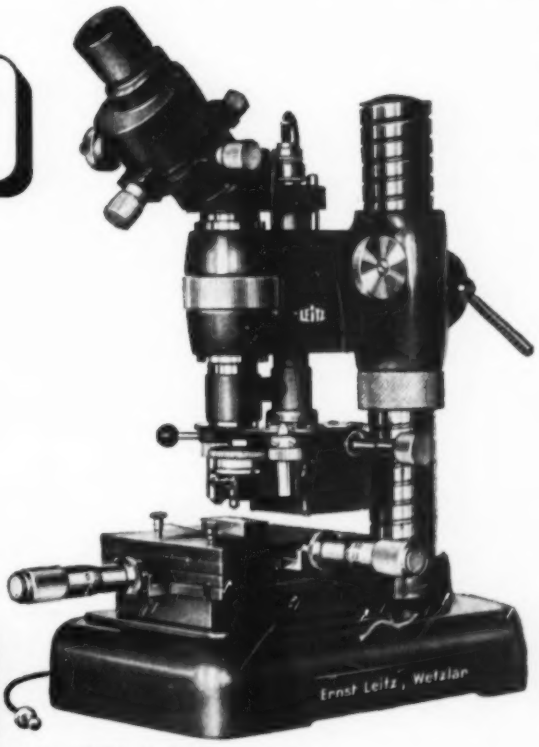
For superficial hardness-testing of small and minute parts without destruction or damage to surface, under positively controlled loads between 15 and 500 grams.

Optionally suitable for indentations by Vickers or Knoop diamond.

Indenter, locating and measuring optics mounted in quick-acting turret for maximum convenience.

Cable release for smooth application of load. Measurements in .001 mm in 400X magnification.

Famous LEITZ optics throughout. Very moderately priced.



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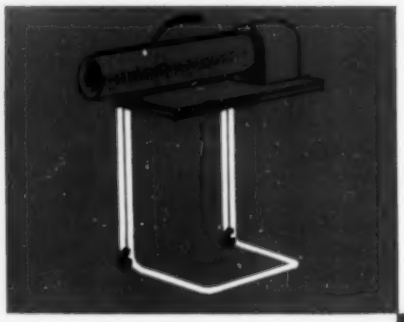
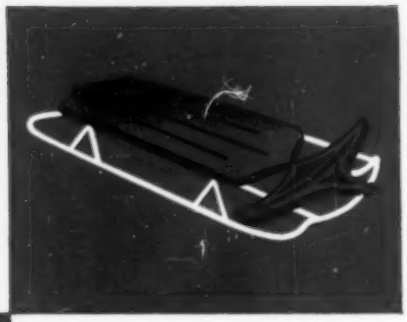
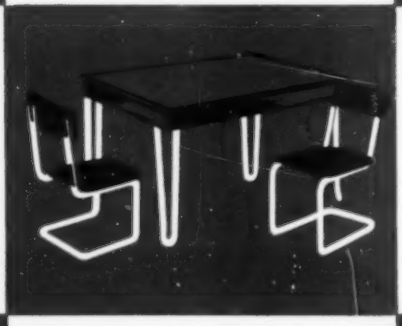


OSTUCO TUBING is versatile!

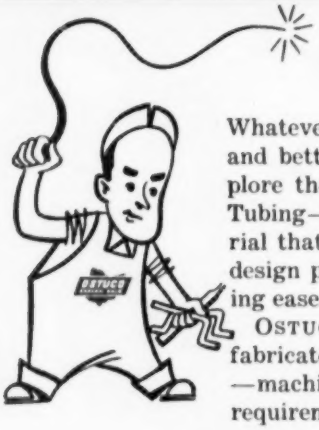


OSTUCO TUBING is versatile!



OSTUCO TUBING is versatile!

OSTUCO TUBING is versatile!



whips new ideas into shape

Whatever your ideas for creating new and better products, it will pay to explore the many advantages of OSTUCO Tubing—the strong, light-weight material that whips even the most stubborn design problems into line with surprising ease.

OSTUCO TUBING can be forged or fabricated beyond recognition as a tube—machined and finished to your exact requirements—quickly joined in assemblies by a large variety of mechanical or welding methods.

Modernized and greatly expanded facilities for *manufacturing, shaping,* and *fabricating* tubing, all at one plant—plus our own steel source as a member of the Copperweld family—enable OSTUCO to speed deliveries, assure uniform high quality, and cut your final costs. Write for informative booklet "Fabricating and Forging Steel Tubing."

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Upsetting • Expanding • Reducing • Beading
End-closing • Spinning • Drilling • Slotting
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Threading • Angle Cutting • And Many Others

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of Copperweld Steel Company

Manufacturers and Fabricators of Seamless and Electric Welded Steel Tubing

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Export: Copperweld Steel International Company, 117 Liberty St., New York 6, N. Y.

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

345. Abrasion Tester
Bulletins on durable precision instrument for testing resistance of surfaces to abrasion. *Taber Instrument*

346. Abrasive
52-page brochure on properties of silicon carbide and manufacturing techniques. Bibliography. *Carborundum Co.*

347. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

348. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

349. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

350. Alloy Steel
68-page "Aircraft Steels" book includes revised military specifications. Also stock list. *Ryerson*

351. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

352. Alloy Tools
44-page book on cast Stellite tools for metal cutting. *Haynes Stellite*

353. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

354. Ammonia Atmospheres
12-page bulletin B-52 on dissociated ammonia furnace atmospheres. *Drever*

355. Anhydrous Ammonia
18-page booklet ammonia and its uses and ammonia installations for metal treating. *Armour Ammonia*

356. Anodizing Magnesium
Article on a new anodic coating for magnesium. *Dow Chemical*

357. Atmosphere Furnace
6-page bulletin SC-163 on Allcase batch type controlled atmosphere furnace. *Surface Combustion*

358. Atmosphere Furnace
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

359. Atmosphere Furnace
Booklets H 53-8 on batch-type radiant tube furnaces for gas carburizing, marquenching, dry cyaniding, and other heat-treating operations. *Surface Combustion*

360. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

361. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chemical*

362. Bearings
Service data on aluminum-on-steel bearings. Comparison with babbitt and bonze bearings. *Johnson Bronze Co.*

363. Belt Finishing
12-page booklet on grinding and finishing, flat or contoured surfaces of all kinds of metal, using coated abrasive belts. *Minnesota Mining & Mfg.*

364. Belt Polishing
Bulletin gives case histories of backstand-belt polishing. *Coated Abrasives Div., Armour & Co.*

365. Bending
28-page booklet on tangent bending machines, some products made on them and processes used. *Cyril Bath*

366. Bending
Catalog on presses for bending, forming, blanking, drawing and multi-punching. *Cleveland Crane & Engineering*

367. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

368. Beryllium
20-page booklet describes beryllium products, including the pure metal, oxide and alloys. *Beryllium Corp.*

369. Bimetal Elements
32-page booklet, "Successful applications of Thermostatic Bimetal," describes 18 uses and gives engineering data. *W. M. Chace Co.*

370. Black Oxide Coatings
Data on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

371. Black Oxide Finish
4-page article "Low-Cost Black Oxide Finish on Steel by Chemical Dip Method." *Mitchell-Bradford*

372. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

373. Black Oxide Finish
Bulletin H-16 on blackening salt. *Park Chemical*

374. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

375. Boron Nitride
Data Sheet 513B on properties and possible uses of boron nitride. *Norton Co.*

376. Brazing
Bulletin 5889 on furnace and induction brazing installations and methods. *General Electric*

377. Brazing
Bulletin 124 on salt bath brazing process. Joints of adequate strength can be developed for most steel assemblies. *Ajax Electric*

378. Brazing Applications
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

379. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel," describes convevor furnace and bright brazing alloy. *Sargeant & Wilbur*

380. Burners
16-page bulletin on selection of gas burners. *Western Products*

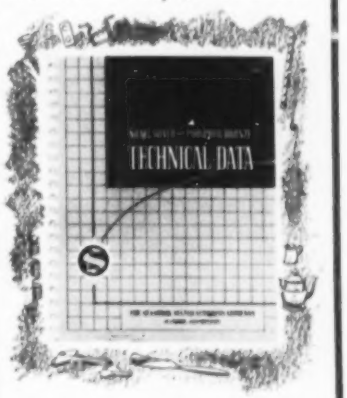
381. Burners
Bulletin on combination gas and oil burner. *Ra-Diant Products*

382. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

383. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

343 Copper Alloy

This 40-page book gives extensive data on nickel silver and phosphor bronze. Six nickel silvers, four phosphor bronzes and 87-13 copper-zinc are included. For each of the eleven alloys, mechanical



properties are plotted against percentage reduction by rolling or drawing. Recommended bend radii are tabulated for many thicknesses and tempers. Cleaning and annealing data are given also. *Seymour Mfg. Co.*

384. Carbonitriding
28-page booklet on nature of process, furnaces, atmospheres, parts carbonitrided and properties. *Armour Ammonia*

385. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs. time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

386. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

387. Castings, Bronze
16-page booklet on sand and centrifugal castings. *Amer. Non-Gran Bronze*

388. Castings, Investment
Production techniques, design, accuracy, advantage of investment casting. *Arwood Precision Casting*

389. Cemented Carbides
64-page catalog 52 gives latest information on carbide tooling. Completely illustrated details on all types of cutting tools.

Mr. Design Engineer
"CAST" YOUR TROUBLES AWAY!

ARWOOD ENGINEERS

**THRIVE ON SOLVING DESIGN PROBLEMS
IN ECONOMICAL MASS PRODUCTION
OF INTRICATE AND COMPLEX PARTS**

ARWOOD'S PRECISION INVESTMENT CASTINGS

- Eliminate prohibitive machining costs, assembly of component parts, losses from waste metal, reduces percentage of rejects.
- Allow wide choice of tougher, longer-life alloys which are difficult to machine.
- Afford maximum design freedom unrestricted by machining limitations.
- Achieve close tolerances.

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Drop us a line and we will have one of our sales engineers call on you and show you how to apply the precision casting process to your industry. Or write for our free booklet "Alloy Selection and Design for Investment Casting".

ARWOOD solved the problem of achieving quantity production of this intricate valve body.

The critical phase was to produce a pressure-tight valve body for use under very special and difficult conditions. The result is this 18-8 stainless steel leak-proof casting produced in quantity by ARWOOD. Tests of each casting by the Helium Mass Spectrometer confirmed leak-proof quality of total production.

Producers of ferrous and non-ferrous precision castings for over a decade.

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Plants: Brooklyn, N. Y. • Groton, Conn. • Tilton, N. H.

Handy tables for grade selection and cutting speeds. *Kennametal*

390. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

391. Clad Metals
24-page booklet on principles of bonding, characteristics of clad metals, methods of cladding and applications. *Superior Steel*

392. Clad Wire
Booklet on properties of nickel-clad copper wire for conductivity use at high temperature. *Sylvania Electric*

393. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

394. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning," discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

395. Cleaning
12-page Bulletin 68 deals with factors to consider in selecting metal cleaning equipment. *Despatch Oven*

396. Coated Abrasives
Bulletin on how to store coated abrasives. Effects of temperature and humidity. *Coated Abrasives Div., Armour & Co.*

397. Coating Aluminum
Bulletin on anodic coating of high hardness for aluminum alloys. *Anodic*

398. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

399. Compressors
12-page Data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

400. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

401. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

402. Controllers
56-page Catalog 1530 on electric and pneumatic controllers. *Minneapolis-Honeywell*

403. Contouring
8-page brochure on three-dimensional duplicating facilities for production of airframe sections and dies and molds for metal products. *MPM, Inc.*

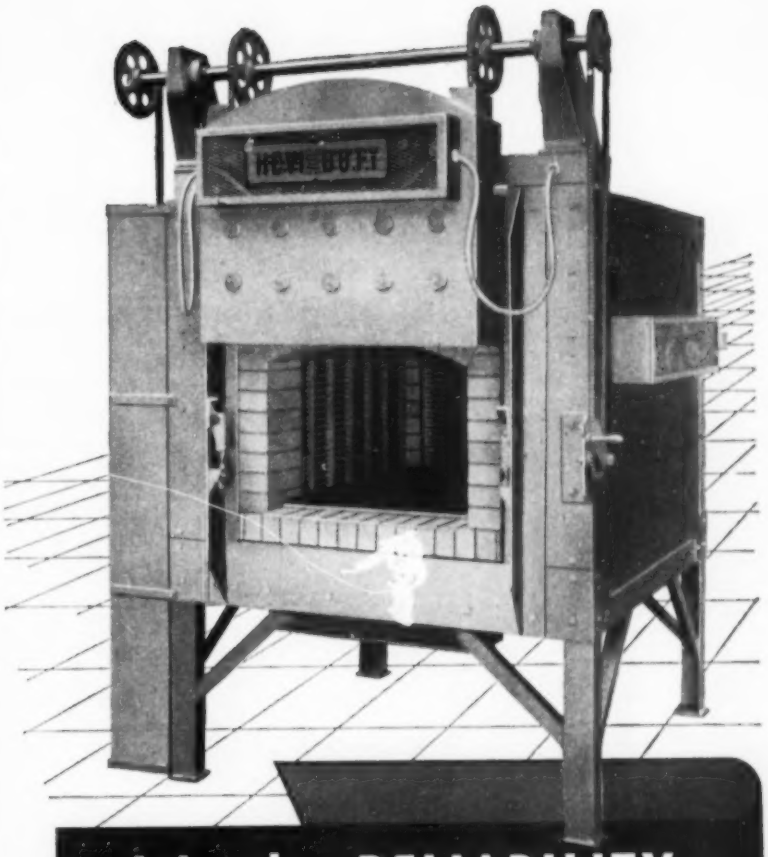
404. Copper Alloys
64-page book on free-cutting brass, copper and bronze. *Chase Brass*

405. Corrosion
Article on corrosion by aqueous solutions at high temperatures and pressures. *Alloy Casting Institute*

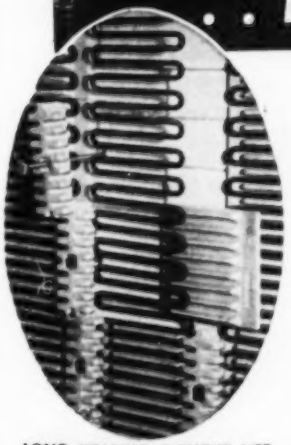
406. Corrosion Data
Bulletin gives comparative resistance to various corrosive media of several stainless steels. *Babcock & Wilcox*

407. Corrosion Proof Cement
12-page bulletin gives corrosion resistance of four types of cement vs. 176 chemical solutions. *Atlas Mineral*

408. Corrosion Resistance
32-page brochure on causes of corrosion



It's the RELIABILITY of HEVI DUTY Furnaces . . . that COUNTS



LONG HEATING ELEMENT LIFE
Round rod return bend heating elements are adequately supported by radiant plates of high grade refractory material.

ADVANCED design, rugged construction and high quality materials are combined with years of furnace building experience to produce Hevi Duty box furnaces. Round rod heating elements and sturdy radiant plate element supports assure continuous performance under severe operating conditions. Users report that reliability and trouble free service are outstanding advantages of Hevi Duty furnaces.

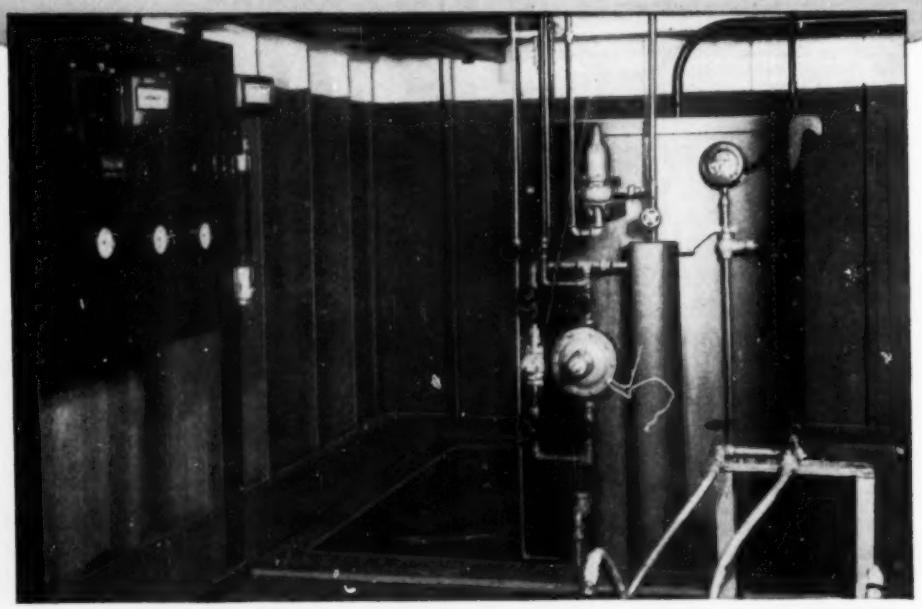
Write for Hevi Duty Bulletin No. HD441

HEVI DUTY ELECTRIC COMPANY
HEAT TREATING FURNACES HEVI-DUTY ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS
MILWAUKEE 1, WISCONSIN

DREVER

AMMONIA DISSOCIATOR

produces **the ideal protective furnace atmosphere**



Shown at right is Drever 1000 CFH Ammonia Dissociator — panel complete with flow meter, pressure gauge, over-temperature protection instruments and temperature control, which is now furnished flush mounted.

"CRACKED" AMMONIA SHOWS TREMENDOUS COST SAVING and UNSURPASSED PERFORMANCE

1—Bright Annealing — Stainless Steels, Nickel and Nickel Alloys, Beryllium Copper, Silicon Copper Alloys and Bronzes, and high and low carbon steels.

2—Clean Hardening — High carbon and high chrome tool steels.

3—Copper Brazing of all types of ferrous metals.

4—Sintering of Powdered Metal Parts.

5—Reduction of Metal Oxides.

6—Bright Annealing of Electrical Steels.

7—Atomic Hydrogen Welding.

8—Radio Tube Sealing.

We can supply COMPLETE STORAGE SYSTEMS for tank car lots of anhydrous ammonia. This reduces the cost of ammonia approximately 75%.

GET ALL THE FACTS about dissociated ammonia, pure, dry hydrogen and nitrogen. **Write today for Bulletin B-52 now on the press.**

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750 E. VENANGO ST., PHILADELPHIA 34, PA.

and means of combating them. Choice of materials for condenser tubes. *Revere Copper & Brass*

409. Corrosion Resistant Linings

Booklet on acid and alkali-proof cements, linings and coatings for pickling tanks, chemical equipment and other uses. *Electro Chemical Eng. & Mfg.*

410. Cutting Oil

Shop notebook gives important facts on right cutting fluid for any machining operation. *D. A. Stuart*

411. Cutting Oil

Folder on sulphurized cutting fluid for a wide range of machining jobs. *Gulf Oil*

412. Degreasing

34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

413. Degreasing

24-page brochure on medium-pH cleaner to follow solvent degreasing or other precleaner. *Northwest Chemical*

414. Degreasing

Pamphlet on properties and use of trichlorethylene. *Niagara Alkali*

415. Dew Point Control

Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

416. Diamond Abrasive

4-page folder on the advantages of diamond abrasives for polishing metallurgical specimens. *Buehler, Ltd.*

417. Die Castings

Booklet on small zinc die castings. For designers and engineers. *Gries Reproducer Corp.*

418. Die Steel

"Die Steels for Hot Work," helps in selection of best grade for particular jobs. *Vanadium-Alloys Steel*

419. Drawing Compounds

Folder on lubricant for forming and drawing of stainless. *Hangsterfer*

420. Electric Furnaces

Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

421. Electric Heaters

64-page Bulletin 1005E on Calrod electric heaters and heating devices. *General Electric*

422. Electrodes

12-page reprint on use of stranded wires in inert-gas shielded-arc welding process. *Air Reduction Sales*

423. Electron Microscope

New 20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

424. Enamel Finishes

Data on Plextone multicolored enamels includes colors, spray equipment, technical tips. *Maas & Waldstein*

425. Fabrication

46-page book shows metal fabrication and production facilities, products and services. *R. C. Mahon*

426. Ferro-Alloys

64-page book describes over 50 metals and alloys produced by company. *Electro Metallurgical*

427. Filters

New folder on coolant filters for micromatic equipment. *Industrial Filtration Co.*

428. Finishing

Six bulletins describing finishing compounds for stainless steel, aluminum, other metals. *Apothecaries Hall*

429. Finishing

52-page book "Advanced Speed Finishing" describes equipment for deburring and finishing. *Almco Div.*

430. Finishing

28-page catalog B-9 on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

431. Flow Meters

24-page manual on application and installation of indicating flow meter. *Meriam Instrument*

432. Forgings

Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U. S. Steel*

433. Forming

86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

434. Forming Dies

Data on roller dies for forming tubes and rolled shapes. *American Roller Die*

435. Foundry Practice

Article on why castings are lost; from "Lavingot Technical Journal." *Lavin*

436. Furnace Belts

44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

437. Furnace Charging

12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

438. Furnace Construction

12-page bulletin on thin-wall construction for furnace enclosures. Engineering drawings. *Bigelow-Liptak*

439. Furnace Controls

Bulletin on instruments and controls for heat treating furnaces. *Hays Corp.*

440. Furnace Maintenance

16-page "Maintenance Guide for Electric Heat Treating Furnaces" on preventive program. *Hevi Duty Electric*

441. Furnaces

High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

442. Furnaces

Bulletin D on salt pot furnaces, forging furnaces, melting furnaces and others. *Eclipse*

443. Furnaces

Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric Furnace*

444. Furnaces

12-page brochure on car furnaces of special and conventional design. *Jet Combustion*

445. Furnaces, Heat Treating

Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

446. Furnaces, Heat Treating

Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

447. Furnaces, Heat Treating

32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

Rapid
RESISTANCE TESTING

with the Rubicon
LIMIT BRIDGE

Built for speedy, accurate production testing of resistors, coil windings, heater elements, percussion caps and other similar items where inspection costs must be minimized.

- Wide Range — 1 ohm to 10 megohms.
- Simple — for use by unskilled operators.
- Fast — speeds of 2000 items per hour possible.
- Sturdy — for year in and year out service.
- Spotlight Index — for easy reading.
- Versatile — suitable for rapid sorting into numerous tolerance bands.
- External Standards — permit automatic temperature compensation when required.

Fully described in Bulletin 100

RUBICON COMPANY
Electrical Instrument Makers
3758 Ridge Avenue Philadelphia 32, Pa.

Rx for "Operation Test Cell"

Norton CRYSTOLON refractory blocks prescribed and engineered for terrific jet engine punishment*

Here's what happens in the 22 test cells at Studebaker's big assembly plant for aircraft jet engines in South Bend:

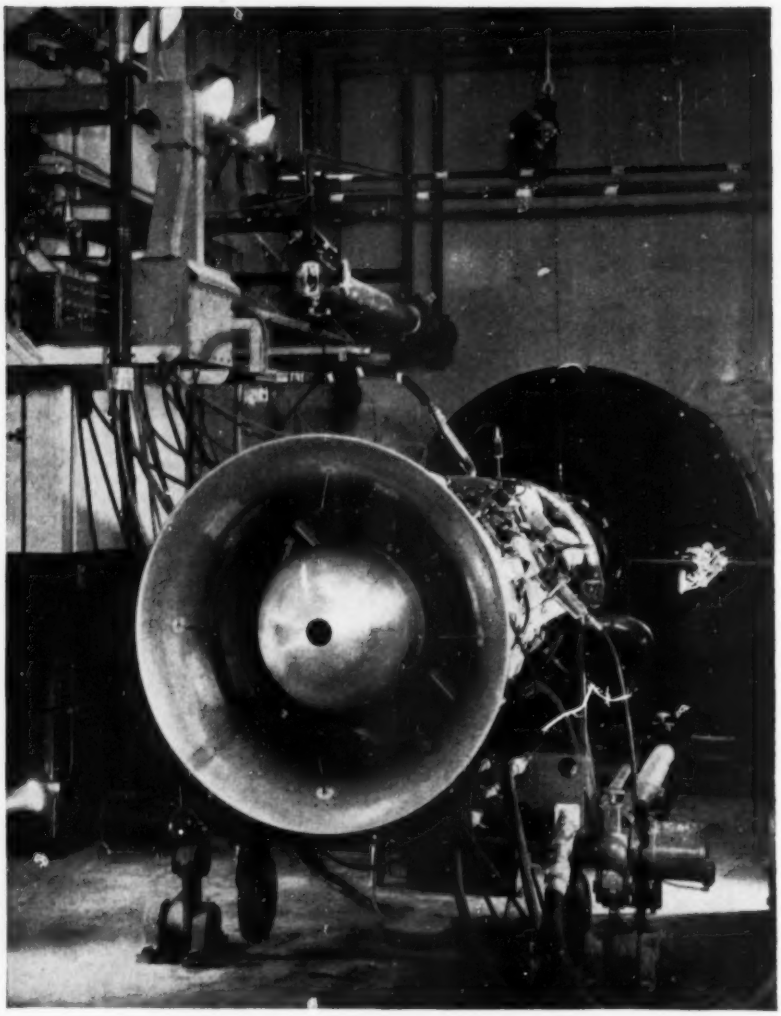
With an ear-splitting roar, the J-47 turbo-jet delivers its full 6,000-pound thrust. The velocity of the exhaust reaches 200 miles per hour, while its temperature hits 400°F in 20 seconds. Behind each engine a large venturi tube, or augmenter, directs the blast into an acoustical chamber, where a huge honeycomb muffler of hollow cement-like blocks absorbs the sound waves and heat.

In this "Operation Test Cell" the first line of defense between engine and acoustical chamber is a movable buffer of CRYSTOLON blocks. Prescribed for their great strength and resistance to abrasion and thermal shock, these Norton Rx refractories have proved themselves the best possible investment. By reducing the intensity and destructiveness of the exhaust, they have eliminated much costly repair work previously necessary in the honeycomb muffler. And after 500 hours of this tough service the CRYSTOLON blocks showed no signs of wear!

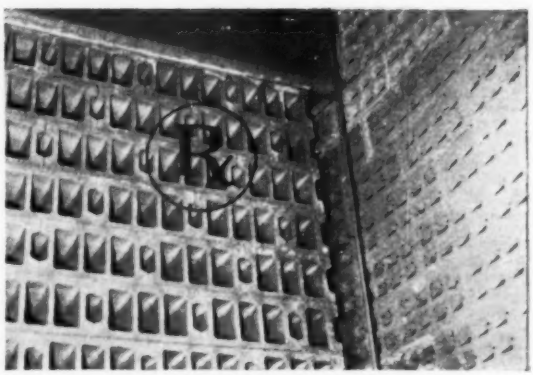
Prescribed For Your Own Applications

Investigate the many Norton Rx refractories — prescribed and engineered for individual applications — that are saving users time and money in a wide range of refractory applications. See your Norton representative, or write to NORTON COMPANY, 321 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries



Ready to Roar. A J-47 turbo-jet engine hooked up for testing in the Studebaker plant. Note opening of augmenter tube at rear of test chamber.



"The Shock Absorber." This movable buffer wall of CRYSTOLON blocks, directly behind the augmenter tube, protects the testing installation by dissipating the exhaust blast.

NORTON

Rx REFRACTORIES

Making better products . . . to make other products better

NORTON COMPANY, WORCESTER 6, MASSACHUSETTS

448. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

449. Furnaces, Industrial
Book 127 on planning expansion, remodeling or modernization of plant. *Continental Industrial Engineers*

450. Gas Burner
Bulletin 122 on radiant tube burner for use in controlled atmosphere furnaces. *North American Mfg.*

451. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

452. Handling Devices
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

453. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

454. Hardness Tester
Data on micro-hardness tester with optional Vickers or Knoop Diamond. *Geo. Scherr*

455. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

456. Hardness Tester
Bulletin ET 469 on new portable hardness tester. *Newage International*

457. Hardness Testing
8-page catalog B-953 on principles and standards of Brinell hardness testing, and types of machines. *Steel City Testing*

458. Heat Resistant Alloy
Bulletin No. 1 on HR-3 (37% Ni, 17% Cr) cast alloy for parts subject to corrosion and high temperatures. *Standard Alloy*

459. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

460. Heat Treating
Discussion of process for heat treating projectile billets in Metal Minutes for December. *Sunbeam Corp.*

461. Heat Treating
Brochure on a quick quench aluminum heat treat furnace. *James H. Knapp Co.*

462. Heat Treating
Folders on steam method of hardening and tempering. Case histories. *Leeds & Northrup*

463. Heat Treating
56-page "Heat Treating Alloy Steels." *Republic Steel*

464. Heat Treating
Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam*

465. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

466. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

467. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. *Pressed Steel*

468. Heating Elements
24-page book on electric heating elements for use up to 2800° F. *Norton*

469. Heavy Duty Cleaning
Booklet on LP cleaner for all metals except aluminum. *Cowles*

470. High Speed Steel
New bulletin on structure and properties of "desegatized" high speed tool steel. *Latrobe*

471. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

472. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

473. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 superalloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

474. High-Temperature Alloys
High temperature work sheet provides valuable suggestions for solving high temperature problems in design and production. *International Nickel*

475. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

476. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

477. Impregnation of Castings
Literature on new impregnating equipment for elimination of porosity in ferrous and nonferrous castings. *Metallizing Co. of America*

478. Induction Heat Control
Data sheet on radiation pyrometer for direct measurement of work being induction heated. *Leeds & Northrup*

479. Induction Heat Control
Sheet 83 on miniature radiation-detecting temperature-measuring device for flame hardening and induction heating. *Minneapolis-Honeywell*

480. Induction Heating
Data folder on megacycle tube-type machines for soldering, brazing, hardening. *Sherman Industrial Electronics*

481. Induction Heating
12-page bulletin 5679 on induction hardening, brazing, annealing at 1000, 3000, and 10,000 cycles. *General Electric*

482. Induction Heating
Bulletin 1440 on system for safety control of induction heating through use of components built into every unit. *Lindberg Engineering*

483. Induction Heating
Bulletin on low-frequency (60-cycle) induction heating furnace for nonferrous metals. *Magnethermic*

484. Induction Heating
New 36 page catalog on high frequency induction heating. *Lepel*

485. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

486. Induction Heating
"Induction Heating" . . . presents case histories of increased production, reduced space, lower costs. *Westinghouse*

487. Instruments
104-page catalog 450 on instruments for

NEW! VERSATILE!

LABORATORY VACUUM FURNACE

The efficient answer to all laboratory furnace problems. Will handle up to 5 lbs. of steel and equal volumes of most other metals. Will reach temperatures up to and in excess of 2000° of C.

Designed for efficient: Vacuum Melting—Alloying Casting—Heat Treating Quenching.

Model F-9

Our *complete* line of high vacuum equipment is available in laboratory and industrial sizes.

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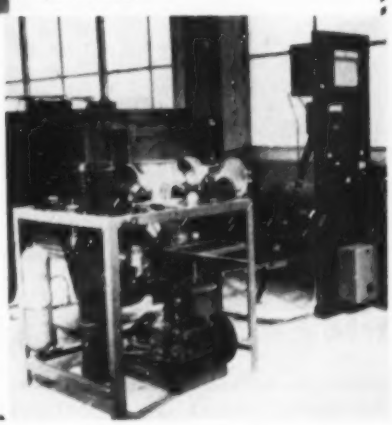
The popular Model F-4 is ideal for production heat treating of small parts.



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Have you a skeleton in your blast cleaning closet?

● How is your abrasive consumption? And what is maintenance costing you on your blast cleaning equipment?

If these two items constitute a skeleton in your blast cleaning closet it is time you heard the story of Controlled T chilled iron shot and grit.

Not only do you get rid of skeletons, but "Controlled T" *guarantees* you a 15% saving on your blast cleaning costs *regardless* of the price you may now be paying for chilled iron shot! The money you save on maintenance—on top of this—is all gravy for you—an extra dividend.

Get in touch with the Hickman, Williams office nearest you and ask for a free copy of "A Primer on the use of shot and grit."

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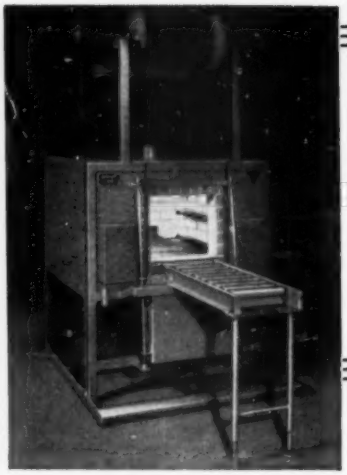

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Dept. Q, 893 Chambers Rd., Columbus 12, Ohio

PERECO ROLLER HEARTH Electric Furnace

SPECIFICATIONS

Chamber Size: 15" w. x 30" d. x 15" h.

Roller Extension: 15" w. x 36" l. (working ht. 30").

Overall Size: 42" w. x 48" d. x 75" h.

Counterbalanced Door: Drop-type with roller mounted top edge.

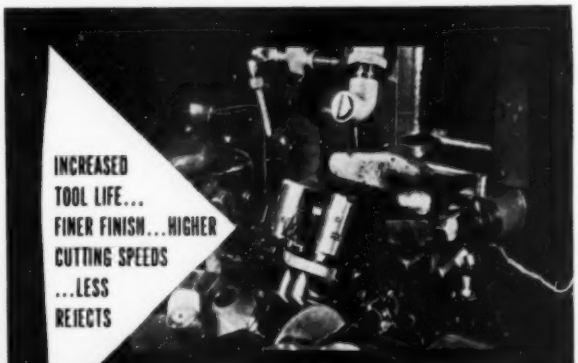
Atmosphere Vent: For release of fumes, located in arch.

Temperature: 1400° F. normal, 1500° F. maximum.

Connected Load: 20 KW. 220 volts, 60 cycle, 1 phase.

Standard and Special Units 450° F. to 5000° F.

PERENY EQUIPMENT COLUMBUS O.



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industry with section on engineering data. *Foxboro*

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32-page book on design and powder metallurgy for iron powders. Tables, graphs of properties. *Antara Products Div., General Dyestuff*

489. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

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16-page bulletin on leak detector for location and measurement of leaks in evacuated or pressure systems. *Consolidated Vacuum Corp.*

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Article on application of extreme low temperatures to metallurgy. Behavior of metals at low temperatures. *Arthur D. Little*

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8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

493. Lubricant
New literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

494. Lubricants
4-page booklet on colloidal graphite, molybdenum disulfide, vermiculite and zinc oxide dispersions for industry. *Acheson Colloids*

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24-page illustrated bulletin gives history of 100 years progress in cutting oils, core oils and lubricants. *Swan-Finch Oil Corp.*

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24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

497. Magnesium Alloys
Pamphlet gives specifications and properties of British Elektron magnesium-zirconium alloys. *Melberk, Inc.*

498. Magnesium Castings
8-page bulletin on manufacture and application of sand molded magnesium castings. *American Radiator & Standard Sanitary Corp.*

499. Magnesium Extrusions
36-page Bulletin DM134, "Section Properties of Magnesium Extrusions," gives values for moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

500. Magnesium Fastening
Article on mechanical fastening of magnesium and precautions in assembly, from Magazine of Magnesium. *Brooks & Perkins*

501. Magnesium Welding
Reprint describes an investigation to evaluate inert-gas-shielded metal-arc welding of magnesium. *Air Reduction*

502. Martempering
Article gives case histories on martempering of aircraft gears. *Ajax Electric*

503. Mechanical Cleaning
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64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

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Data on nondestructive sorting tool for raw, semi-finished or finished parts. *Dice*

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20-page book on desk-type metallograph. *American Optical*

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Bulletin describes the Kentron microhardness tester. *Kent Cliff Laboratories*

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Bulletin DH-114 on Tukon hardness testers in research and industrial testing. *Wilson Mechanical Instrument*

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40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

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Bulletin on generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co.*

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8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

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Reprints on Land-Polaroid method of X-ray film processing. *Picker X-Ray*

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Recent developments, factors affecting plating techniques, recommended procedures, in "Technical Advisor" No. 23. *Reynolds Metals*

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20-page bulletin on use of portable hardness testers and accessories. *Ames Precision Machine*

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Bulletin on high density process for fabrication of precision high strength parts from iron powders. *Pow-Met Industries*

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8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

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Bulletin on mechanically-operated induction furnace for precision casting. *Ajax Electrothermic*

(*Continued on page 32-A*)

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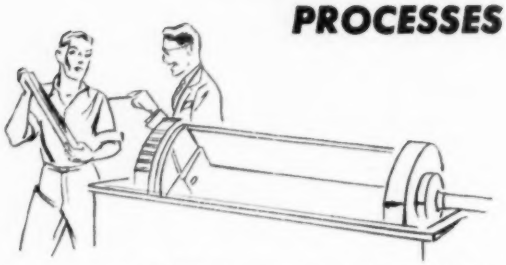

Available for warm or cold plating baths, Seymour Bright Nickel Processes accelerate work and improve results. Write for complete information.

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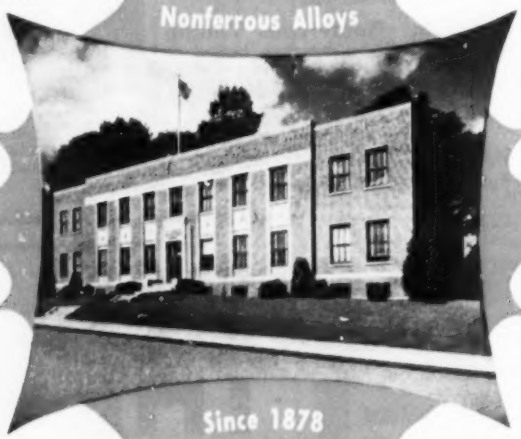

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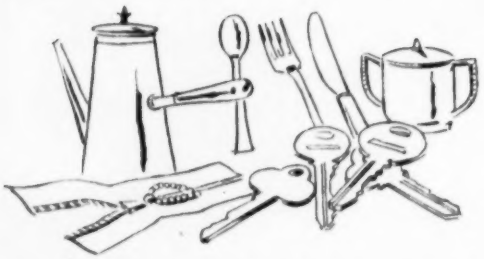

Seymour Nickel Silver is an ideal silvery white base for plated ware, a smooth-flowing alloy for spun and drawn articles. Free-cutting, non-corrodible, it is excellent for screw-machine products. It is widely used in the manufacture of keys, zippers, musical instruments, fine plated silverware, surgical instruments, fishing tackle, spectacle frames, etc.

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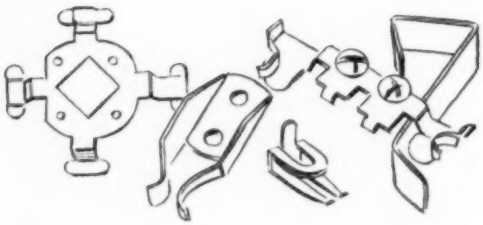

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MP 2-54

(Continued from page 29)

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8-page pamphlet on seven different metals in plated or enameled finishes. Surfaces are plain, crimped and striped. *Apollo Metal*

525. Pressure, Vacuum Gages
32-page Catalog 7001 on gages for vacuums to 10 "mm. Hg and pressures to 150,000 psi. *Minneapolis-Honeywell*

526. Protecting Aluminum
Folder on Alodine for protection of painted or unpainted aluminum. *American Chemical Paint*

527. Protective Coatings
Guide to chemicals and processes for metal protection. *American Chemical Paint*

528. Pyrometer Supplies
56-page Users' Manual and Buyers' Guide. Specifications, prices, thermocouple calibration data. *Bristol Co.*

529. Pyrometers
8-page catalog No. 85 on optical pyrometer. *Pyrometer Instrument*

530. Pyrometers
12-page Bulletin 713 on indicating and controlling pyrometers. Functional diagrams of installations. *General Electric*

531. Pyrometers
Information on Xactemp pyrometers; also Xactline straight-line temperature control for use with any standard controller. *Claud S. Gordon Co.*

532. Pyrometers
New 24-page thermocouple and accessory bulletin. *West Instrument*

533. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

534. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton*

535. Quenching
Bulletin 820 on automatic quenching tanks for use with continuous heat treating equipment. *Am. Gas Furnace*

536. Quenching
Article in "Heat Treat Review" compares hot oil and molten salt quenching. *Surface Combustion Corp.*

537. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil*

538. Radiation Protection
12-page booklet on films for determining amount of radiation. Used in research laboratories, nondestructive testing laboratories. *Du Pont*

539. Radiography
Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. *Westinghouse*

540. Recorder Controller
4-page bulletin on multi-point circular chart recorders. *Fielden Instrument Div.*

541. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

542. Refractory Cement
Data on castable cement for temperatures to 3100° F. *Refractories Div., Carborundum*

543. Refractory Mixes
16-page bulletin 315 on properties and applications of sillimanite super-refractory ramming mixes and furnace patches. *Chas. Taylor Sons*

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Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

545. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

546. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

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548. Salt Baths
75-page manual on salt baths for case hardening and heat treating. *DuPont*

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Data on continuous feed, cabinet-type sandblast machine and applications. *Leiman Bros., Inc.*

550. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

551. Shot and Grit
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552. Shot Peening
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553. Shotblasting
16-page "Primer on the Use of S Grit." Problems of blast cleanin tions. *Hickman, Williams*

554. Sintered Carbides
Catalog of made-to-order tung bide components gives typical sh sizes. *Sintercast Corp.*

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20-page spark test guide featu diagrams of 13 standard tool steels. *Carpenter Steel*

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562. Stainless Bars
28-page technical book on stain bars includes processing in about cutting, welding, forging, machining, and heat treating. *Ludlum*

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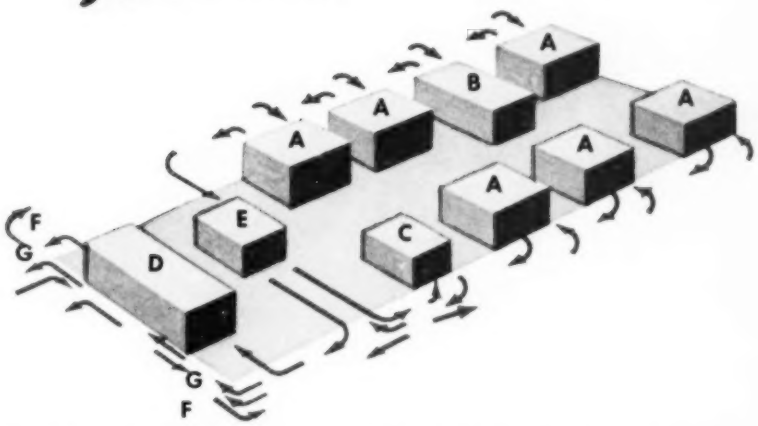

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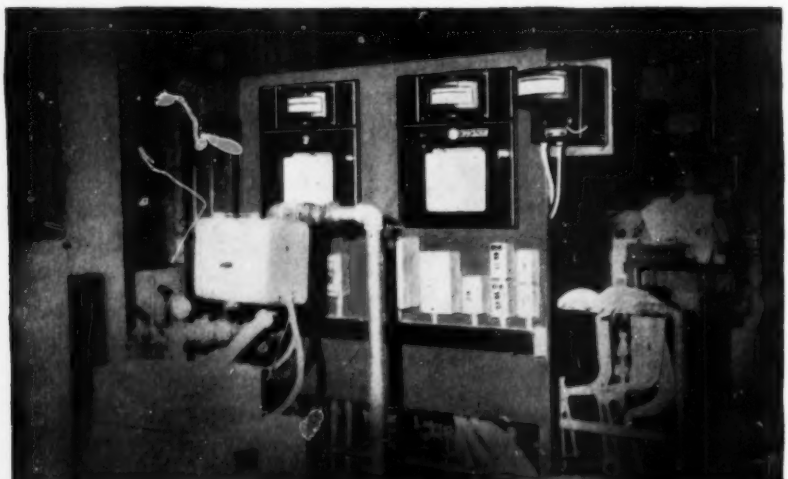

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etin gives examples of five types of ss steel castings. *Sivyer*

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ge reprint "Tips on Stainless for ft Hydraulics." Design and fabrica- *Superior Tube*

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letin F-6149 on types of control sys- and how to select the right one for purposes. *Wheelco*

Testing Machine
ge bulletin on SR-4 universal test- achine of 50,000 lb. capacity. *Bald- ima-Hamilton*

Testing Machines
age catalog on hydraulic testing nes. 10 models described; also acces- . *Riehle*

Thermocouple Data
age Bulletin TC-9 on thermocouples, ion detectors, resistance bulbs, ac- ies. *Wheelco*

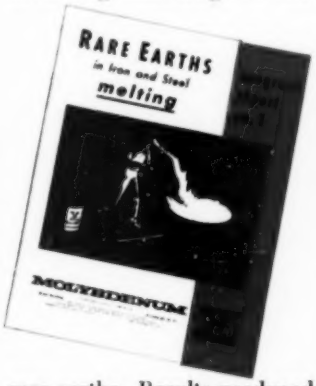
Thermocouple Wire
ge catalog on thermocouple and ex- n wires. *Thermo Electric Co.*

581. Tin
New bulletin, How Straits Tin Can Help You. *Malayon Tin Bureau*

582. Tool and Die Steels
26-page book on six oil and air hard- ening steels for high-production tools and dies. Many uses. *Bethlehem Steel*

344 Rare Earths

A progress report on the use of rare earths in iron and steel melting tells the story of advancing knowledge of the



rare earths. Results produced with misch metal and the newer rare earth combinations on wrought steel, cast iron and cast steel are described and illustrated. *Molybdenum Corp.*

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Information on "Sure-Wear" process for heat treating high-speed cutting tools. *LR Heat Treating Co.*

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Bulletin on equipment for industrial vacuum metallizing. *Optical Film Eng'g*

593. Vacuum Metallurgy
Bulletin gives résumé of vacuum metallurgical operations and research and development facilities and services available. *National Research Corp.*

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Bulletin V-51B describes line of vacuum pumps. *Kinney Mfg.*

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6-page bulletin on bronze welding rods. Table gives ASTM, AWS and Government specifications. *Titan Metal*

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54-page manual on welding processes for stainless with recommendations and settings for arc, spot and pulsation welding. Soldering and brazing. *Republic Steel*

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140-page manual on conveyor design, belt specifications, metallurgical data. *Cambridge Wire Cloth*

599. X-Ray Diffraction
Bulletin 8A-3505 on film or direct recording X-ray diffraction apparatus. *X-Ray Div., General Electric*

February, 1954

9	353	377	401	425	449	473	497	521	545	569	593
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2	376	400	424	448	472	496	520	544	568	592	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name

Title

Company

Address

City and State

Postcard must be mailed prior to May 1, 1954—
Students should write direct to manufacturers.

What Mr. Tubes Can Do For You

—about pressure tubing

When it comes to pressure tubing, you're wise to talk to somebody who knows your problems. Mr. Tubes, your nearby B&W Tube Representative, serves the oil, chemical and power industries . . . and related fields . . . faithfully and efficiently. He is constantly concerned with tubing problems his customers encounter, and he devotes a lot of his time to helping find the right answers to questions of pressure and temperature.

Mr. Tubes can do a lot for you. Next time pressure tubing is on your mind, call on him.

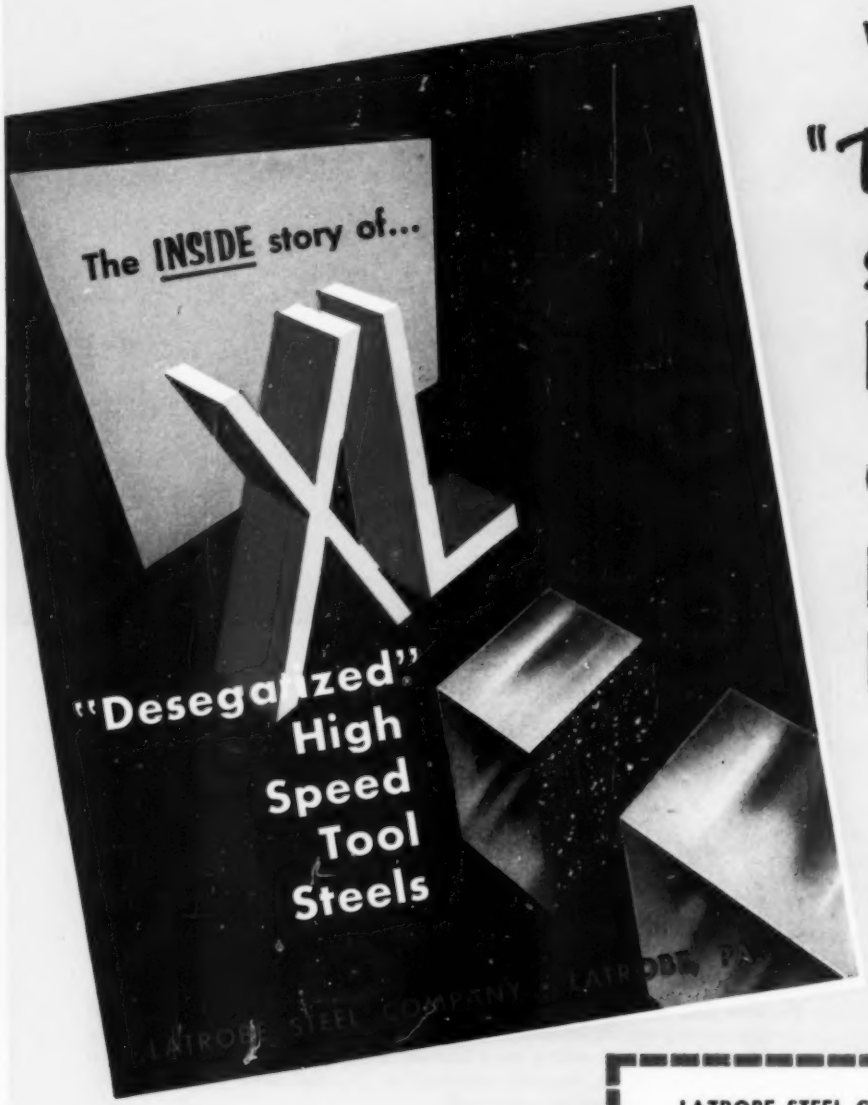
B&W SEAMLESS and WELDED TUBES

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION

Beaver Falls, Pa.—Stainless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

TA-1802(P)

Latrobe's new high speed steels



with

"Built-in" sulphide lubricants

assure

lower cost through higher production

Send for this folder today!

LATROBE STEEL CO., Latrobe, Pa. MP-2

Please send data on "XL" steels to:

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STEEL COMPANY
LATROBE, PENNSYLVANIA

Branch Offices and Warehouses • Boston Buffalo Chicago Cleveland Dayton Detroit Hartford Hillside Los Angeles Milwaukee Philadelphia Pittsburgh St. Louis Toledo

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Here's why it pays to know your HSM

HONEYWELL SUPPLIES MAN

D. A. Somers, Honeywell Supplies Man in the Philadelphia area, shows Harry Baldwin, purchasing agent of Ajax Engineering Corp., Trenton, N. J., the type of Brown thermocouple protecting tube that will give long life and high sensitivity in an aluminum melting furnace.

Personalized service is the foundation of the HSM Plan. Your HSM man gives you valued assistance not only in selecting the right pyrometer supplies, but also in setting up a custom-fitted plan for buying that can cut your inventories, simplify purchasing . . . and save you a big percentage of your annual supplies bill.

Hundreds of companies are now using this Plan. Your nearby HSM will be glad to discuss how it can work in your own plant . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Aves., Philadelphia 44, Pa.

MINNEAPOLIS **Honeywell**

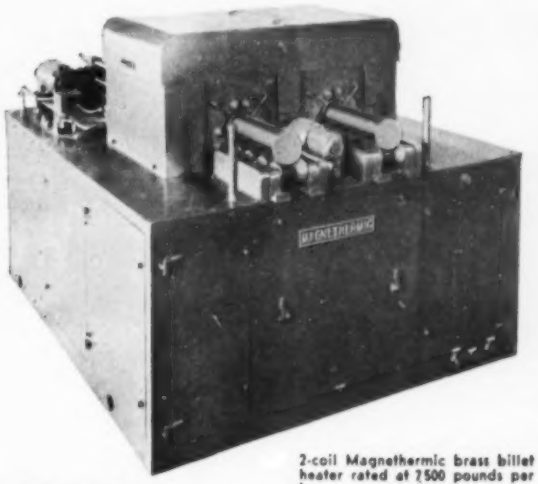
BROWN INSTRUMENTS

First in Controls

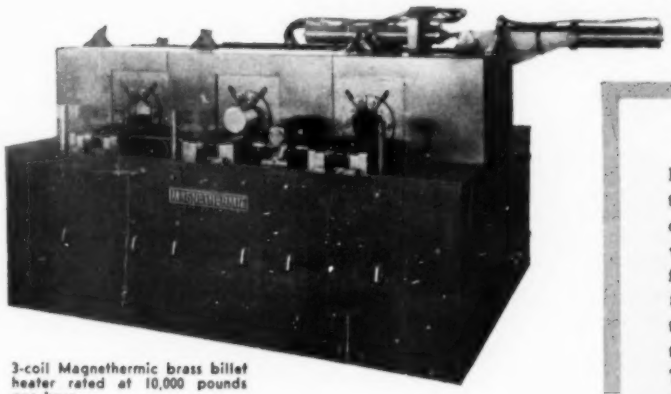
Induction Heaters for Brass and Copper Billets

REDUCE OPERATING COSTS

Magnethermic 60-cycle brass and copper billet heaters, now in operation, prove that they do reduce operating costs. Billets are heated in two or three minutes rather than hours. Temperature control is extremely accurate . . .each billet is discharged at exactly the same temperature. No warm-up time is required. On initial start ups, press the button, and in two or three minutes, heated billets are ready for further processing. No need to schedule billets ahead of time. Not more than three billets are in process at any one time.



2-coil Magnethermic brass billet heater rated at 7500 pounds per hour.



3-coil Magnethermic brass billet heater rated at 10,000 pounds per hour.

MAINTENANCE

Furnace damage is caused by heat. In a typical Magnethermic heater, the heating chamber is a tube 8" in diameter, 24" long, and water cooled for long life. In a conventional furnace, the heating chamber may be 40 ft. long, 8 ft. wide and 3 ft. high. It stands to reason that the latter will require many times the maintenance that the induction coil requires. Then too, no need to shut down when relining the coil. Operate on the other coils, or put in a spare coil. Coils can be changed in ten minutes and relined in an hour or two.

ALL SIZES

Magnethermic makes a single, two, or three-coil heater for any production requirement needed. All heaters are shipped completely assembled. Installation cost is at a minimum. Working conditions are ideal and floor space is negligible.

Heaters will operate equally well on extrusion billets, piercer billets, or wire bars. If you have a heating problem, let one of our engineers discuss it with you. A letter or phone call will receive prompt attention.

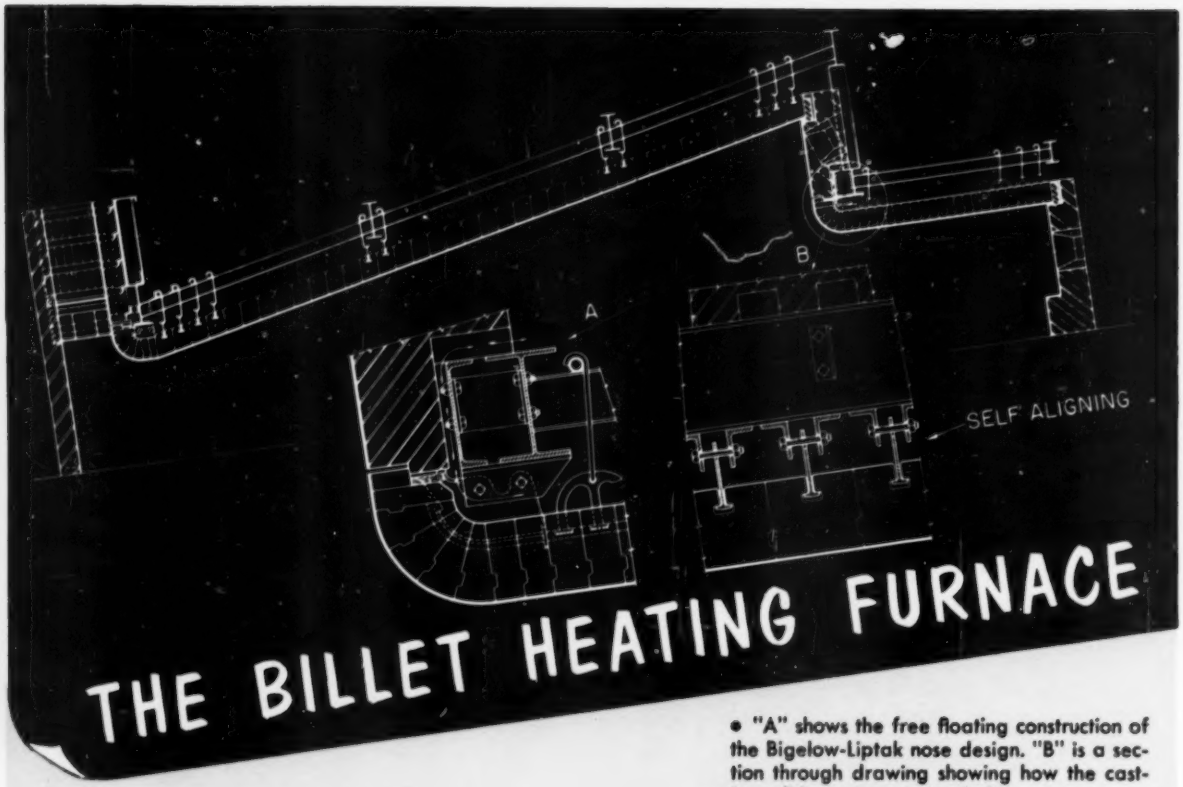
60-CYCLE

MAGNETHERMIC®

corporation

3990 SIMON ROAD YOUNGSTOWN 7, OHIO

INDUCTION HEATING



THE BILLET HEATING FURNACE

• "A" shows the free floating construction of the Bigelow-Liptak nose design. "B" is a section through drawing showing how the castings slide on supporting bolts.

THAT LEADS WITH ITS NOSE...

THE PROBLEM . . .

A new radial nose tile for billet heating furnaces. Previously, cumulative expansions of rigidly hung nose tile in wide metallurgical furnaces had caused mechanical failures of tile and castings . . . plus "shut down" losses of production time.

THE ANSWER . . .

A *free floating* nose designed by Bigelow-Liptak engineers to control expansion movements at this highly vulnerable point. The free floating feature is only possible with unit-suspension construction . . . another Bigelow-Liptak development.

THE RESULT . . .

Steady, everyday, on-the-line effectiveness.

Write today for more information on industrial furnace enclosures.

BIGELOW-LIPTAK *Corporation*

and Bigelow-Liptak Export Corporation
2550 W. GRAND BLVD. • DETROIT 8, MICHIGAN

UNIT-SUSPENDED WALLS AND ARCHES

In Canada: Bigelow-Liptak of Canada, Ltd., *Toronto, Ontario*

ATLANTA • BOSTON • BUFFALO • CHICAGO • CINCINNATI • CLEVELAND • DENVER • HOUSTON • KANSAS CITY, MO. • LOS ANGELES • MINNEAPOLIS • NEW YORK
PITTSBURGH • PORTLAND, ORE. • ST. LOUIS • ST. PAUL • SALT LAKE CITY • SAN FRANCISCO • SAULT STE. MARIE, MICH. • SEATTLE • TULSA • VANCOUVER, B.C.

The Park Neutra-gas Story:

No sludge, no de-carb in neutral salt baths rectified by Ansul methyl chloride!*

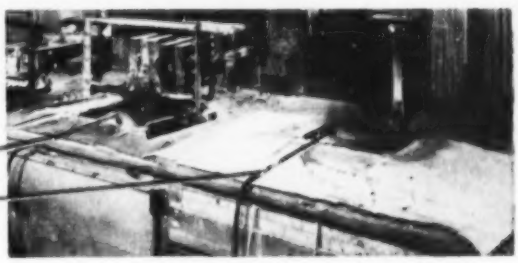
A patented development of Park's research laboratory, the Neutra-gas process efficiently and economically neutralizes chloride base salt baths . . . maintaining them free of de-carb in temperatures ranging from 1350°F. to 2300°F. The decarburizing oxides present are chemically converted back to chlorides by passing methyl chloride through the molten baths.

No solid rectifiers and their subsequent sludging are needed. No fresh salt additions are required except to replace drag-out. Fluidity of salt is maintained like new and sluggishness caused by solid rectifiers is eliminated.

Complete details of the Neutra-gas process plus valuable information on neutral salt baths, their operations and uses, are described in a technical bulletin available to you by mailing the attached coupon.

* Truly neutral chemically. Alkalinity can be maintained at zero.

At Commercial Steel Treating Corp., in Detroit, salt bath furnaces are daily cleansed of all impurities. Rectifying gas is bubbled into Park Nu-Sal Neutral Salt molten at its operating temperature of 1500°F.



Even high-speed hardening baths up to 2300°F. are easily maintained neutral. At Commercial, both pre-heat and high heat are rectified daily to zero alkalinity. Rectification is at 1850°F. in the high heat, done either on idling time or when furnaces are being used for hardening high carbon, high chrome die steels. Salt is Park Pre-heat 117, and Park High Heat 175-S.

Ansul Methyl Chloride (CH_3Cl) is a liquefied gas, 99.98% pure (by weight).
Patent number — 2474680 — Neutra-gas Process license fee, $25.00 per year.

Third in a series of advertisements describing Park processes on the job.

• Liquid and Solid Carburizers • Cyanide, Neutral, and High Speed Steel Salts • Coke • Lead Pot Carbon • Charcoal • No Carb • Carbon Preventer • Quenching and Tempering Oils • Drawing Salts • Metal Cleaners • Kold-Grip Polishing Wheel Cement

Park

PARK CHEMICAL CO.
8074 Military Avenue • Detroit 4, Michigan

Send free bulletin on Park Neutra-gas Process.

Name_____ Position_____

Company_____

Address_____

City_____ State_____

At the NATIONAL SUPPLY COMPANY,
Torrance, California

Flame hardening with *GAS* reduces highly specialized tooling

Flame hardening of a gear for a drilling rig rotary is accomplished at National Supply Company by means of a semi-automatic setup. The heated tooth is moved by an indexer to a water spray for quenching.

TO REDUCE THE NUMBER of highly specialized and costly tooling in a production of oil well drilling machinery, plant engineers of the National Supply Company have devised new methods of flame hardening which utilizes natural gas.

Using these methods, the flexibility of Gas permits the adaptation of a comparatively small number of versatile machines and burners to flame harden many different parts. The large variety of shapes and sizes and the relatively small number of parts of each type make the highly specialized tooling prohibitive in cost. To overcome this obstacle, Gas is mixed with oxygen in order to attain high enough temperatures to heat the surface of steel parts above the transformation temperature. Then, water or oil rapidly quenches the heated part to room temperature. This produces a continuous hard surface of uniform depth that will resist wear by abrasion over a softer, more shock resisting core.

This is but one example of the many ways in which Gas and Modern Industrial Gas Equipment are being utilized throughout the production lines of industry. For more information on how Gas is being used to increase the efficiency of heat treating production lines, contact your Gas Company Representative or Gas Equipment Dealer.

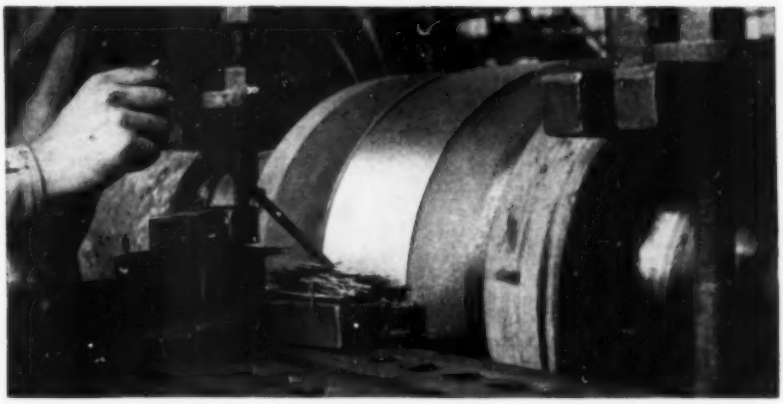
AMERICAN GAS ASSOCIATION • 420 Lexington Avenue, New York 17, New York

MORE AND MORE... THE TREND IS TO GAS

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation



Red Sabre Bit Does Double Duty

Roll-dressing in a mill where steel bars are rolled had long been considered an operation requiring two types of tool steels. For the roughing cuts they used tool bits made of high-speed steel. And for the finishing cuts, they turned to water-hardening steels.

But someone got to thinking, Why not try Red Sabre? Then maybe one tool steel could be used for both jobs.

So Red Sabre was put to work, and is giving an excellent account of itself on alloy-iron and cast-steel rolls having a hardness of 48 to 60 Shore.

The roughing operation is shown above. The hardened-and-ground block-cutter tool, 1¼ in. high, 1½ in. wide, and 8¼ in. long, and with four cutting edges, is making a cut approximately .006 in. deep. The finishing cut, less than .001 in. deep, is made without changing the tool set-up. Both operations are performed at a surface speed of 40 in. to 60 in. per minute, depending on the diameter of the roll.

Red Sabre is our super-high-speed steel, containing approximately 1.50 carbon, 12.00 tungsten, 5.00 vanadium and 5.00 cobalt. It is unusually resistant to abrasion and wear, and has higher red-hardness than most high-speed steels.

Red Sabre tool bits, hardened to a minimum of Rockwell C-65 and accurately ground, are stocked in all standard sizes. If you'd like to try them out in your shop, put it up to your tool steel distributor. Or if you prefer, order direct from us at Bethlehem, Pa.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

This Is Why We Anneal Most Tool Steel Bars

In the majority of cases, bars of Bethlehem tool steel are furnished in the annealed condition, both to users and distributors. There are two important reasons why this is so:

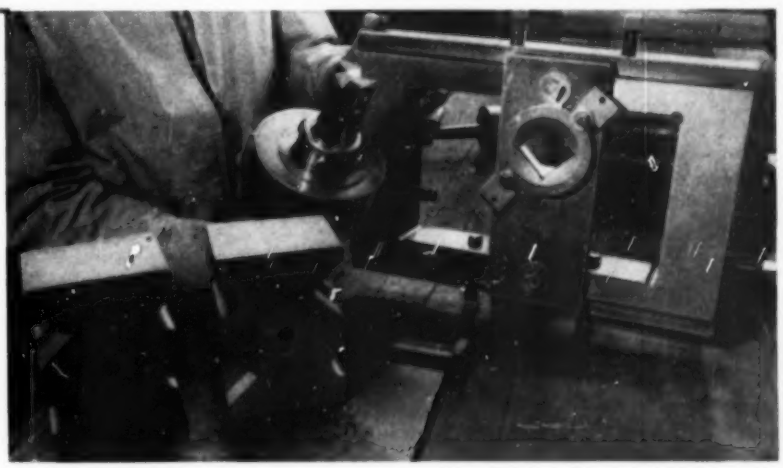
1. The process of annealing makes it possible to remove the stresses occurring in the as-rolled or as-forged bars. If such stresses were not removed, they could very well lead to cracking, resulting in delay and increased shop costs.

2. With many types of tool steels, it is necessary to obtain the lowest degree of hardness in order to secure the best machinability. But for other grades of tool steels, low hardness is undesirable. For this reason, annealing is carefully controlled to produce the proper degree of hardness for the grade involved.

Here's another point to remember—excessive scaling and decarburization must be avoided during annealing. We find the bell-type, controlled-atmosphere furnaces used in our tool-steel mill excellent for this purpose. In fact, with these furnaces we obtain results which are far superior to what is possible when other types of annealing equipment are used.

MACHINE BOLT FORMING DIES MADE OF CR-MO-W

Making forming dies which are capable of turning out thousands of square-head machine bolts each day is a task calling for a top-notch grade of tool steel. That's why Bethlehem Pacific, the largest maker of bolts on the West Coast, selected Cr-Mo-W (Chrome-Moly-Tungsten) tool steel for making dies used in bolt manufacture. Like many other tool-steel users, they find Cr-Mo-W ideal for jobs involving shock or drastic temperature changes, as well as for applications where heat-checking is a problem. Cr-Mo-W, our general-purpose type of hot-work tool steel, is air-hardening, and has good red-hardness and good machinability.



New Jobs
for the World's
Most Useful
Metal
—Straits Tin

Tin mining in Malaya. Here a test boring is being removed.

New tin-alloy platings improve products, cut costs

The number of new ways you can use Straits Tin to make better products at lower cost is today growing faster than ever, and lower cost means higher profit.

New tin-alloy platings, for example, are giving increased protection against corrosion to steel.

Tin-zinc and tin-cadmium platings have been found to be many times as resistant to corrosion as either zinc or cadmium alone.

Tin-copper electrocoatings are increasingly useful. Red bronze can now be used as a more durable undercoating for chrome—white bronze for applications similar to those of silver plate.

And because tin is as handsome as it's adaptable, a new tin-nickel alloy is proving itself a more attractive, more corrosion-resistant decorative plating than the conventional chromium on nickel copper.

New plating alloys represent just one of the ways Straits Tin can do more for you today.

Over a third of the global tin output is mined and smelted in Malaya. Known as Straits Tin, this metal is over 99.87% pure, and is world-famous for its absolute reliability of grade.

Whether you're planning a new product, working to improve an old one, or simply seeking ways to avoid the squeeze between rising manufacturing costs and resistance to higher product prices, a careful reappraisal of the properties of Straits Tin may uncover a profitable answer to your problem.

Write now for any information you may need about versatile, plentiful, economical Straits Tin.

A free copy of our new bulletin "How Straits Tin Can Help You," is yours for the asking.

MALAYAN TIN BUREAU

THE MALAYAN TIN BUREAU

Dept. 350, 1028 Connecticut Ave., Washington 6, D.C.

The Brazing is Practically Free!

...when you combine it with salt bath carburizing or hardening

Any material that can be brazed at all can be brazed in an Ajax Electric Salt Bath Furnace—much faster, better and usually at lower cost. But that's only part of the story!

Where a steel assembly for brazing also requires carburizing or hardening, the entire job can be done in a single heating operation so that brazing is practically free. Note examples on this page.

The "secret" lies in brazing with brass during the carburizing operation. This money-saving method is possible only with a salt bath furnace, thanks to its greater heating speed—so fast that no dezincification of the brazing metal occurs. Moreover, the steel assembly is brazed and carburized below 1700° F. instead of at 2050° F. as required for copper brazing. Thus, distortion and grain growth are greatly reduced and furnace operating costs are less. Conclusive tests prove that brass-brazed joints are fully as strong as those of copper.

For straight brazing employing copper, silver or aluminum, the Ajax furnace offers from 4- to 6-times faster heating cycles. Amazingly accurate temperature control minimizes distortion. Selective heating is easy. Scaling or decarburization are avoided and floor space requirements are only a fraction of those required with any other production brazing system.

Write *for Ajax Bulletin #72 and Reprint #124*

Bring *production batches of your materials to the Ajax Metallurgical Service labs for on-the-job demonstrations of Ajax efficiency.*

AJAX ELECTRIC COMPANY, INC.
910 Frankford Ave. Philadelphia 23, Pa.

Associated companies: Ajax Electric Furnace Corp.; Ajax Electrothermic Corp.; Ajax Engineering Corp.

A

Ajax combined carburizing and brass-brazing reduced rejects 50%, effected savings of 51% and improved the quality of this wrench jaw. Steel jaw insert is brazed in place and the entire assembly carburized in one heating at 1675° F. Brazed joints must pass a test of 40,000 psi.

ONE HEATING DOES

Carburizing and brazing of this motor starter assembly are done simultaneously in a single Ajax salt bath with one heating of the work. A water quench completes the job. A conventional carburizing bath produces a case depth of .015" in 50 minutes.

QUALITY IMPROVED—

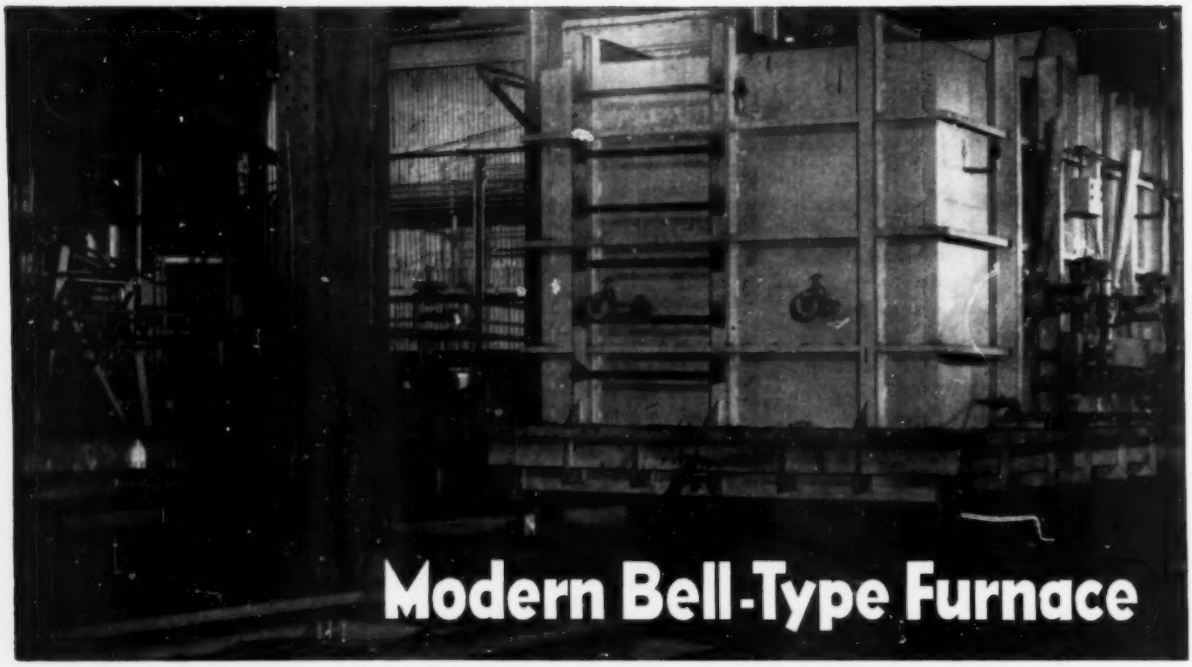
The laminations of this SAE-1010 steel stapler bracket are securely brass-brazed at the same time the surface is being carburized. Wearing surfaces are file hard. Distortion is less than .005". The entire carburizing-brazing operation was done in 20 minutes.

WARP-FREE HARDENING
BRAZING

Warpage on this magnetic lock part is negligible thanks to complete protection during hardening in a neutral salt bath. The flange is securely brass-brazed to the steel cup in the same operation. Brazing metal is confined neatly to the joint—does not spread over the parts.

AJAX

World's largest manufacturer of electric heat-treating furnaces exclusively



Modern Bell-Type Furnace

ANNEALS ALLOY BARS

This modern rectangular annealing furnace will anneal bars up to 30′ long in controlled atmospheres. This is another important reason why Youngstown Cold Finished Alloy Bars are so satisfactory.

Metallurgical characteristics, machinability and cold working properties are benefited by use of such modern equipment. Tolerances and all phases of the manufacture of Youngstown Cold Finished Alloy Bars are subjected to rigid quality control by a single integrated organization—from mining of the ore to shipment of the finished product.

Youngstown Cold Finished Alloy and Carbon Steel Bars are furnished in standard shapes and sizes, in both coils and straight lengths. For further information, phone or write our nearest District Sales Office.

At left: Furnace bell being lifted from load of annealed bars. Above: Bell in annealing position on loaded car.

QUALITY YOUNGSTOWN SERVICE

Youngstown COLD FINISHED CARBON AND ALLOY STEEL BARS

THE YOUNGSTOWN SHEET AND TUBE COMPANY *Manufacturers of Carbon, Alloy and Yoloy Steel*

General Offices: Youngstown, Ohio - Export Office: 500 Fifth Avenue, New York 36, N. Y.

SHEETS - STRIP - PLATES - STANDARD PIPE - LINE PIPE - OIL COUNTRY TUBULAR GOODS - CONDUIT AND EMT - MECHANICAL TUBING - COLD FINISHED BARS - HOT ROLLED BARS - BAR SHAPES - WIRE - HOT ROLLED RODS - COKE TIN PLATE - ELECTROLYTIC TIN PLATE - RAILROAD TRACK SPIKES

For Atlantic Automatic Co., Cleveland, Ohio:

Tool Life Increased Over 200%!

PARTS FOR GEARS & CAR TRANSMISSIONS are just a few of the many delicate machine tool products Atlantic turns out. Cities Service Chillo Cutting Oil has helped Atlantic maintain their great reputation for quality products.

For the services of a Cities Service Lubrication Engineer... Write Cities Service Oil Company, Sixty Wall Tower, New York City 5, New York.

CITIES SERVICE
QUALITY PETROLEUM PRODUCTS

"Cities Service Chillo Cutting Oil Has Proved To Be The Difference Between Ordinary And Quality Production In Our Shop!"

Here's Atlantic Automatic's story in their own words: "One of our tougher jobs recently was machining SAE 446 Stainless Steel with two forming, one threading and three drilling operations. The critical operation was drilling a .025 inch diameter hole, ⅛ inch deep. The drill would soon pack with chips and break. When a Cities Service Lubrication Engineer was called in, he recommended our using Chillo 44.

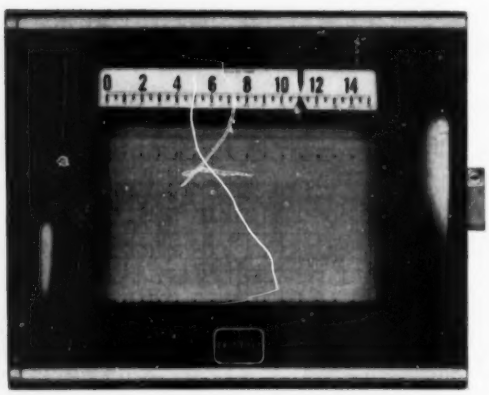
"This light-colored oil did the trick. DOWN TIME WAS CUT IN HALF AND DRILL LIFE INCREASED OVER 200%!

"We use Cities Service Chillo 44 to machine all types of metals covering a range of machinability from brass to stainless on our Brown and Sharpe 00G, 0G and 2G Automatics. It has proved to be the difference between ordinary and quality production in our shop!"

WHAT'S NEW AT BRISTOL . . . . WHAT'S NEW AT BRISTOL

Bristol makes DRY CELLS in potentiometers as obsolete as the wall telephone!

NEW ***Bristol electronic Dynamaster potentiometers and pyrometers give you No-Batt CONTINUOUS STANDARDIZATION without dry cells***



The wall telephone has long since joined the parade to the past.

Now Bristol's development of No-Batt continuous standardization has put dry cells for instrument work in the same category.

Here's what the new Bristol instruments offer:

- **CONTINUOUS STANDARDIZATION** – which eliminates need for dry cells – supplies voltage that is continuously compared with standard cell.
- **CONTINUOUS OPERATION – NO TIME OUT.** With continuous standardization, the potentiometer is free to continuously measure, record, and control. No time out or interruption is required for periodic standardization.
- **NO STANDARDIZING MECHANISM.** Continuous standardization is taken care of electrically. The absence of standardizing mechanism simplifies the instrument considerably.

For the complete story on the modern Bristol Dynamaster, write for free 35-page booklet P1245. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

LOOK FOR OUTSTANDING NEW DEVELOPMENTS FROM BRISTOL

BRISTOL

THE DEPENDABLE GUIDEPOST OF INDUSTRY

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Make it **WEIGH LESS** and **LAST LONGER** with

N-A-X

HIGH-TENSILE STEEL

You can design light weight, longer life, and economy into your products by including N-A-X HIGH-TENSILE in your plans.

- It is 50% stronger than mild steel.
- It is considerably more resistant to corrosion.
- It has greater paint adhesion with less undercoat corrosion.
- It has high fatigue life with great toughness.
- It has greater resistance to abrasion or wear.
- It is readily and easily welded by any process.
- It polishes to a high lustre at minimum cost.

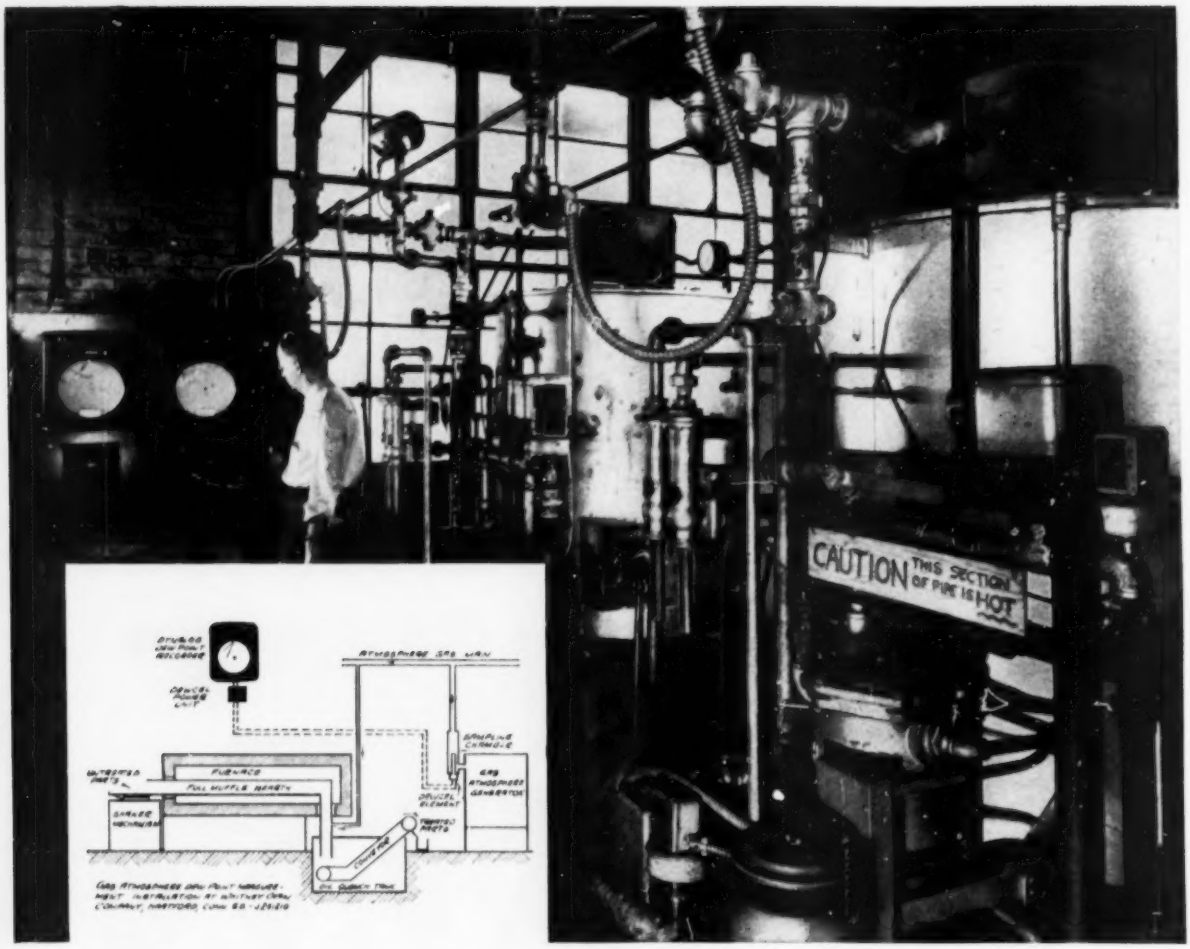
And with all these physical advantages over mild carbon steel—it can be cold formed as readily into the most difficult shaped stamping.

Sound like something for you? Ask for full facts and think of N-A-X HIGH-TENSILE when you re-design.

GREAT LAKES STEEL CORPORATION

N-A-X Alloy Division • Ecorse, Detroit 29, Michigan

NATIONAL STEEL CORPORATION



How Whitney Chain Improved Heat Treating with **DEWCEL*** Moisture Measurement

Whitney Chain Co., in Hartford, Conn., uses two Gas-Atmosphere Generators to supply a battery of heat treating furnaces in producing chain plates, pins, rollers, and bushings for their Power Transmission and Conveyor Chains. Correct atmosphere conditions in the furnaces must be maintained for proper carbon control and retention of finish on these hardened and carburized parts.

Formerly it was necessary to make complicated time-consuming spot checks of these conditions. Now, *Foxboro Dew Point Recorders* monitor continuous samples of the gas from the generators . . . provide continuous dew point records which permit the operator to maintain desired gas quality.

The heart of this precise measuring system is its humidity-sensitive element — the exclusive Foxboro Dewcel which senses the dew point temperature to within ±1° F. . . . rapidly responds to any change in moisture content. Complete illustrated description of the Foxboro Dew Point Recording System is contained in Engineering Data Sheet 340-7. Write for copy.

*Trade Mark

THE FOXBORO COMPANY, 522 NEPONSET AVE., FOXBORO, MASS.

FOXBORO
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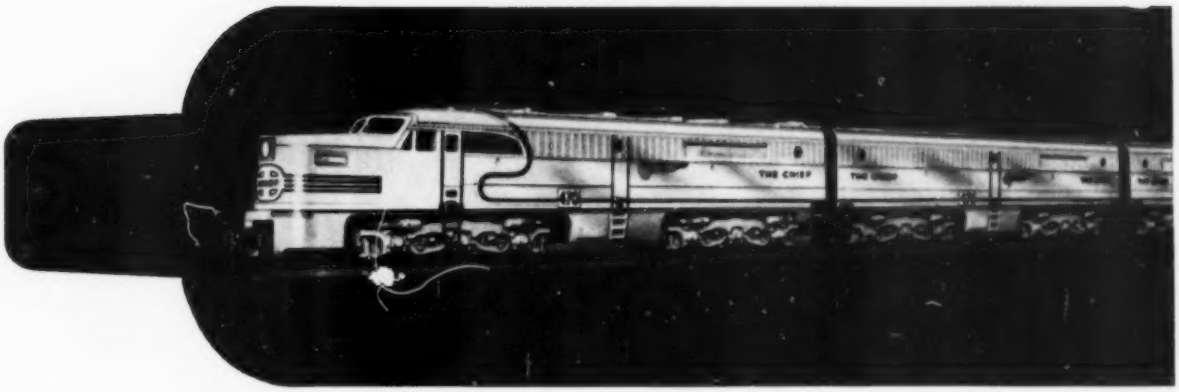
INSTRUMENTS that Improve Product Quality

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

How Armour ammonia cuts costs in sintering powdered metal parts



A. C. Gilbert uses a protective atmosphere of dissociated ammonia to sinter 102 parts for this American Flyer model train

Protective atmospheres of dissociated ammonia have proved efficient and economical for sintering powdered metals, as well as bright annealing, bright heat treating and other metal treating applications. Dissociated ammonia provides an easily controlled atmosphere at much lower cost than hydrogen. One cylinder of ammonia yields the equivalent of 34 cylinders of hydrogen—and is much less costly!

A. C. Gilbert has been using dissociated ammonia since 1951 to provide a protective atmosphere for sintering powdered metal parts of all kinds. They have had such success—in efficiency and economy—with powdered metallurgy and with dissociated ammonia that their equipment is running 24 hours a day, 6 days a week.

Gilbert is one of many satisfied customers using Armour ammonia. In many cases, Armour men have given help and advice on installations. That's just part of Armour's service to our ammonia customers. Since 1947, Armour has sponsored a fellowship at Massachusetts Institute of Technology for the study of metal treating processes using ammonia. The men of Armour's Technical Service Department are equipped to handle and answer any problem arising with ammonia installations for metal treating.

The booklets offered at right will show you how to put this know-how to work for you. Write today for your free copies. If your problems are unusual or pressing, write giving full details of your requirements.

You can depend on
Armour's Ammonia and Service

CLIP AND MAIL THIS TODAY!

Please send me copies of
the following booklets:

- ☐ "Applications of Dissociated Ammonia"
- ☐ "The Nitriding Process"
- ☐ "Ammonia Installations for Metal Treating"
- ☐ "Carbonitriding"

Name ..... *Title* .....

Firm .....

Address .....

City ..... *Zone* ..... *State* .....

ARMOUR *Ammonia Division*

Armour and Company • 1355 West 31st Street
Chicago 9, Illinois

Reduce plate weight *10%*

. . . insure unvarying quality

To inspect pressure and bulk storage vessels J. B. Beaird Co. uses two OX-250 x-ray units. These versatile units can be mounted on stationary jib cranes, mobile jib cranes, truck-type, or semi-automatic production type housings.

100% x-ray inspection results in higher quality products with substantial savings

When the J. B. Beaird Co., Inc., of Shreveport, La., introduced 100% x-ray inspection, they reduced the plate thickness of their pressure and bulk storage vessels by 10%. This is permissible because ASME and API-ASME codes state that a 10% higher weld efficiency factor can be used when welds are 100% x-ray inspected.

The resulting savings in steel alone amount to several tons per tank, with a consequent reduction in shipping costs. In addition, Beaird now uses less welding time and materials.

Allowing for films, chemicals, operator's time and equipment amortization and upkeep — the use of two OX-250 x-ray units permits substantial savings on each vessel produced. More important, Beaird customers are assured unvarying high quality.

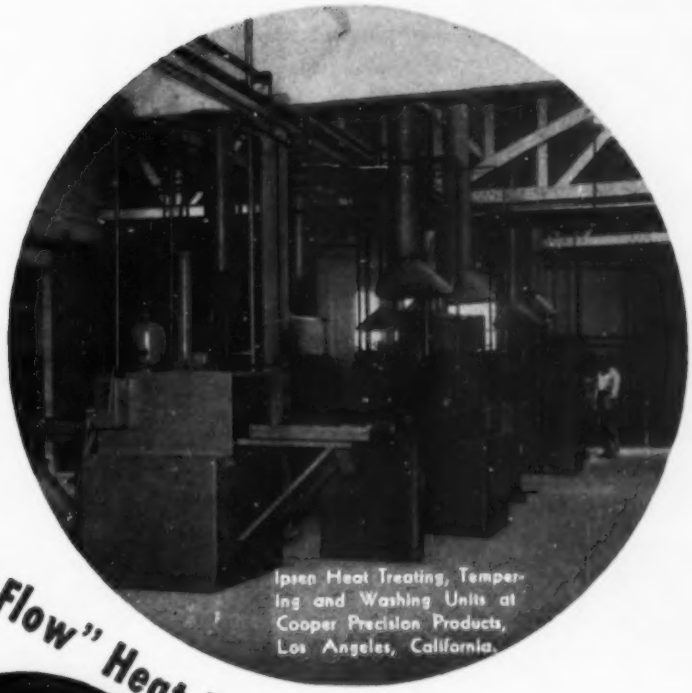
No matter what your non-destructive testing needs, there's a General Electric x-ray unit to match your requirements. Your G-E x-ray representative can base his recommendation on 25 models, ranging from 140,000 to 15,000,000 volts. Call him today, or write X-Ray Department, General Electric Company, Milwaukee 1, Wis., Rm. A**S**24.

Like all G-E x-ray apparatus — OX-250 can be yours — without initial capital investment — on the Maxiservice® rental plan.

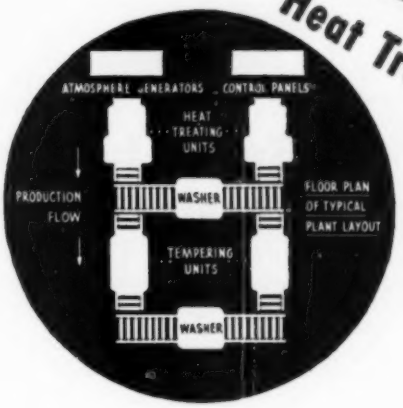
You can put your confidence in —

GENERAL ELECTRIC

How IPSEN "Production Flow" Heat Treating Reduces Work Handling



Ipsen Heat Treating, Tempering and Washing Units at Cooper Precision Products, Los Angeles, California.



NOW with Ipsen Units, you can modernize your heat treating department, improve quality and cut costs! Each self-contained Ipsen 100% Forced Convection Heat Treating Unit can harden, carburize, carbon restore or carbonitride. When used with Ipsen Washers and Tempering Units, connecting roller sections permit uninterrupted movement of work load through all units at furnace level.

Ipsen Automatic Heat Treating and Tempering Units have complete cycle and atmosphere control for uniform results and for bright and absolutely scale free work. Straight-through design of Ipsen equipment gives you maximum efficiency in work handling.

Send Samples—You'll want to know how heat treating the "Ipsenway" can be applied to your work. Send samples of your work for processing and for a cost estimate.

Write for new literature — illustrating and describing the complete line of Ipsen equipment, including new Automatic Dew Point Controller.

AUTOMATIC Ipsen HEAT TREATING UNITS

Universal Production Units in Standard Sizes—100 to 2,000 Lb./Hr.

IPSEN INDUSTRIES, INC. 723 SOUTH MAIN STREET, ROCKFORD, ILLINOIS

Why it pays to specify BARRETT® BRAND ANHYDROUS AMMONIA FOR Metal Treating

ECONOMY

For metallurgical uses, anhydrous ammonia is one of the most economical sources of hydrogen and nitrogen. One 100-pound cylinder of Barrett® Brand Anhydrous Ammonia gives you 4500 cubic feet of mixed gases when dissociated at normal temperature and pressure. Or approximately 3375 cubic feet of hydrogen and 1125 cubic feet of nitrogen.

FAST DELIVERY

Barrett Brand Anhydrous Ammonia is stocked coast-to-coast in 150, 100 and 50-pound cylinders. An adequate supply of cylinders in all sizes helps assure fast delivery in the size you want.

TROUBLE-FREE USE

Every cylinder valve is carefully inspected before it leaves the plant. This assures you of properly working valves and trouble-free use when cylinders reach you.

FREE TECHNICAL HELP

Technicians specially trained in the use of Anhydrous Ammonia for metal treating stand ready to help you at all times without cost or obligation. Write for free booklet, "Guide for the Use of Barrett® Brand Anhydrous Ammonia in Cylinders."

For greater savings, better service and better performance, specify Barrett® Anhydrous Ammonia—the brand with the bright green cylinder caps.

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Nitrogen Division

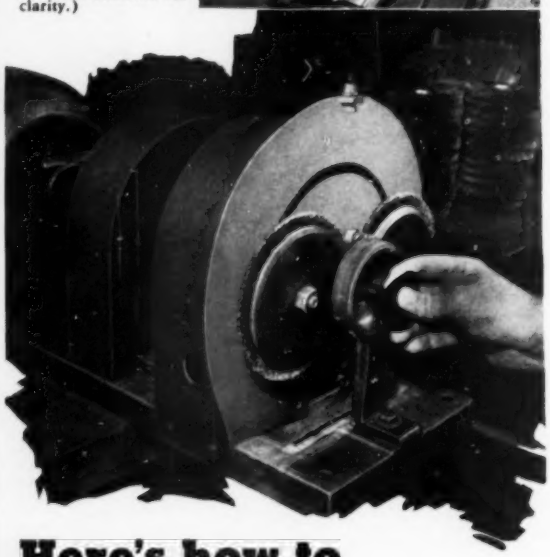
ALLIED CHEMICAL & DYE CORPORATION

40 Rector Street, New York 6, N. Y.

FIRST IN AMMONIA SINCE 1890

The rubber base of each valve is roughened by a Pittsburgh brush to secure a better bond when vulcanizing the valve to a tube.

Pittsburgh brushes remove excess rubber which spills onto valve cap thread during vulcanizing operation. (Guard housing has been removed for clarity.)



Here's how to brush rubber

A. Schrader's Son, Brooklyn, New York, uses Pittsburgh brushes in the production of tire valves for leading tire manufacturers. In one operation, two brushes remove the excess rubber which flows around the valve threads during the vulcanizing process—750 valves per hour are cleaned in this manner!

Another Pittsburgh brush on a buffing machine roughens the rubber base of the valves to secure a better bond when vulcanizing the valve to a tube. In this operation, the Pittsburgh brush was chosen because it outlasts competitive makes.

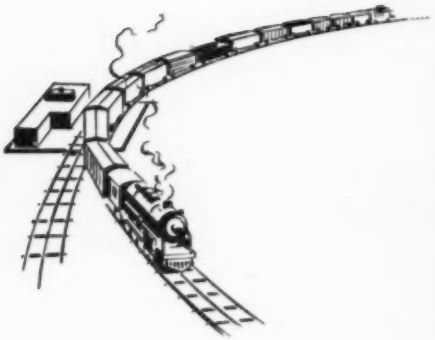
WRITE TODAY for your free copy of our new booklet that shows thru actual case histories, how Pittsburgh can help cut *your* brushing costs. Address: Pittsburgh Plate Glass Company, *Brush Div.*, Dept. W-14, 3221 Frederick Ave., Baltimore 29, Md.

PITTSBURGH *Power Driven* **BRUSHES**

BRUSHES • PAINTS • GLASS • CHEMICALS • PLASTICS • FIBER GLASS

PITTSBURGH PLATE GLASS COMPANY

IN CANADA: CANADIAN PITTSBURGH INDUSTRIES LIMITED



Lionel is on the right track

Here is an Inconel pusher tray designed by ALLOY ENGINEERING COMPANY, Berea, Ohio. The Inconel basket being loaded on the tray (above) contains parts that will be sintered at 2050° F. Each tray is "double-stacked" to utilize furnace capacity.

Pusher trays, like those used at The Lionel Corporation in Irvington, New Jersey, take a two-way beating.

Here's what a daily grind those tough, oxidation and corrosion-resisting Inconel® trays go through.

First, they are loaded with two Inconel baskets holding twenty pounds of parts each. Then they start on the journey through the 1650° to 2050° F. furnace, pushing the tray ahead. The furnace atmosphere is exothermic or endothermic reducing gas. They spend 35 or 40 minutes in both the pre-heat zone and the hot zone and then two hours in the cooling zone.

And they go through this cycle as many as five times a day for as long as 15 months without failure. All they require is an occasional maintenance of welds and straightening. These trays are designed and fabricated by Alloy Engineering Co., Berea, Ohio.

Inconel may be the answer to your problem, too. You'll find that it has extra strength at high temperatures... that it is ductile and readily fabricated. Welded joints in Inconel are as strong and heat resistant as the alloy itself.

Write to Inco for your copy of an interesting booklet for the heat treating industry. Ask for "Keep Operating Costs Down . . . When Temperatures Go Up."

THE INTERNATIONAL NICKEL CO., INC.
67 Wall Street New York 5, N. Y.

INCO TRADE MARK

Inco Nickel Alloys

Inconel... *for long life at high temperatures*

MURRAY-WAY the automatic way / the economical way / the better way

to POLISH . . . BUFF . . . GRIND . . . FILTER

Whatever your job . . . whatever your problem . . . Murray-Way automatic equipment will do that job better and more economically.

These are just a few illustrations of Murray-Way's success in beating production cost with the finest automatic equipment available.

You can depend on Murray-Way engineering, Murray-Way experience, Murray-Way equipment to solve your production problems.

A. Micro-Polish—Continuous Strip Polishing Installation
B. Vertical-Platen Conveyor
C. Horizontal-Platen Conveyor
D. #51 Universal Polishing Head —One of Several Standard Polishing Heads
E. The Automatic, Self-Cleaning, Compact Filter
F. #72 Series Belt Polishing Head
G. Indexing Dial Table
H. Six Micro-Polish Units in Series

P. O. Box 180, Maple Road, E.
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MURRAY WAY CORPORATION

Our seventy-fifth year

With a warm feeling of accomplishment and a deep pride of workmanship we start our seventy-fifth year of manufacturing quality die blocks and forgings.

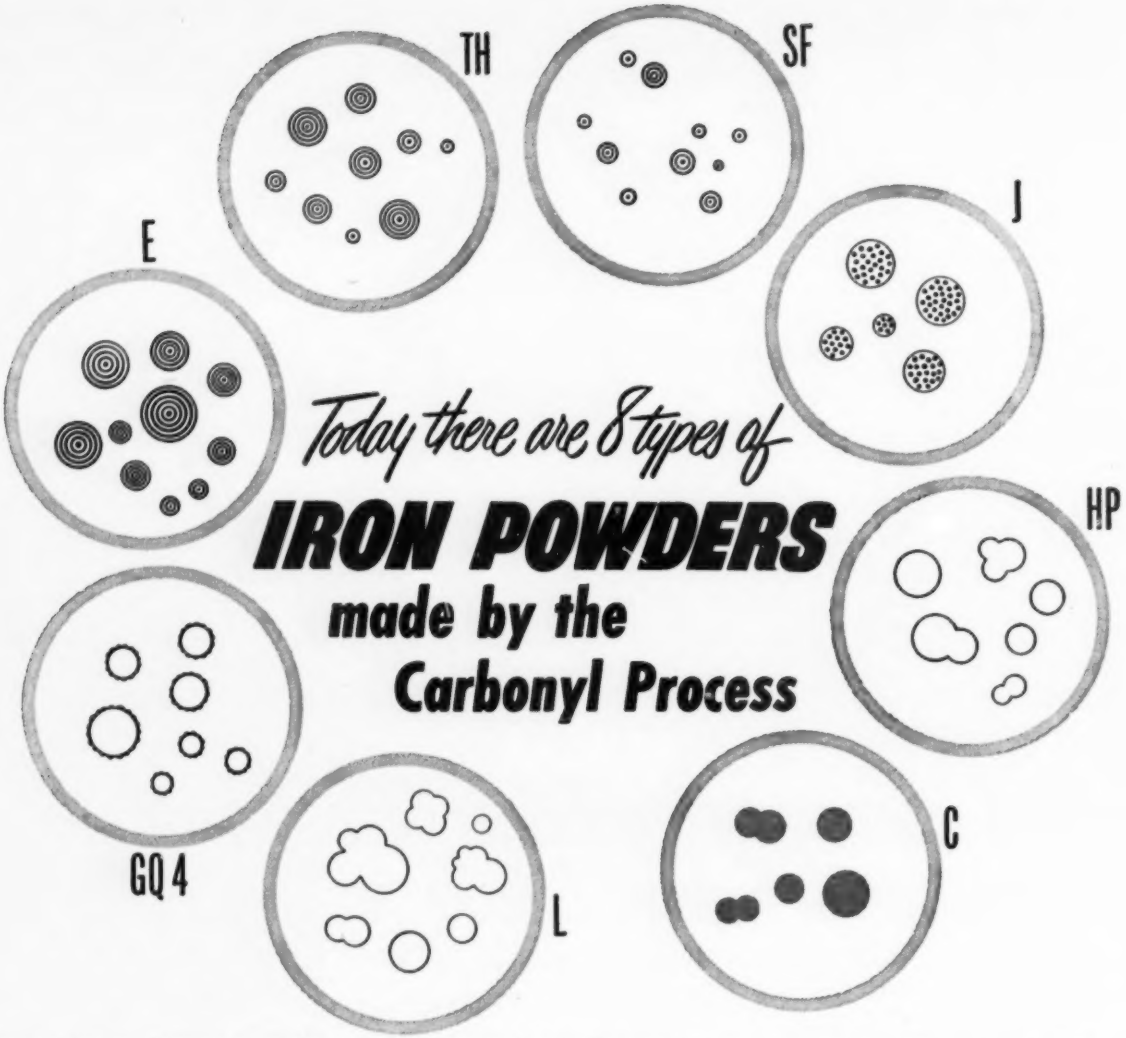
Since 1879 it has been our policy to produce only the best. That this has proved sound, is evident in the host of loyal customers whose confidence and faith in our products and service has helped to make this Diamond Anniversary Year a reality.

We sincerely thank you.

A. Finkl & Sons Co.

2011 SOUTHPORT AVENUE • CHICAGO 14

ELECTRIC FURNACE STEELS • DIE BLOCKS • FORGINGS



Today there are 8 types of

IRON POWDERS

made by the Carbonyl Process

These powders are microscopic particles of extremely pure iron—spherical or agglomerations of spheres. The particles differ in size, in structure and in chemical composition and are thus adaptable to many different uses. Produced in eight carefully controlled types, the particle sizes range from one-half to twenty microns in diameter. The iron content of some types is as high as 99.6—99.9%.

Now widely used in high frequency cores for many communications systems, several types may also be used as alloying agents, as catalysts, in pharmaceuticals, magnetic fluids and many applications in powder metallurgy.

The powders make for ease of sintering. Added in metal parts, they also permit controlled shrinkage of the finished sintered part. In other applications, they impart greater ductility and strength to the finished piece. Desirable properties and qualities of powdered metal parts are enhanced by using these powders—either in whole or in part.

This 32-page book offers you the most comprehensive treatment yet given to the characteristics and applications of G A & F Carbonyl Iron Powders. 80% of the story is told with photomicrographs, diagrams, performance charts and tables. . . . We invite you to call upon our research facilities and Technical Service Department for assistance in developing new applications or new products involving the use of any of these powders. Kindly address your inquiry to Department 71.

E Steel-like, concentric shell structure, weight average diameter 8 microns

TH Steel-like, concentric shell structure, weight average diameter 5 microns

SF Steel-like, concentric shell structure, weight average diameter 3 microns

J Alloy, face-centered cubic crystals, higher resistivity, weight average diameter 8 microns

HP Soft, pure iron, high magnetism, weight average diameter 10 microns

C Soft, low hysteresis, weight average diameter 10 microns

L Soft, larger particles, many agglomerates, weight average diameter 20 microns, pure iron

GQ 4 Soft, refractory coating on particle surface, weight average diameter 8 microns

GA&F® CARBONYL IRON POWDERS

MEMBER mpa METAL POWDER ASSOCIATION

ANTARA® CHEMICALS

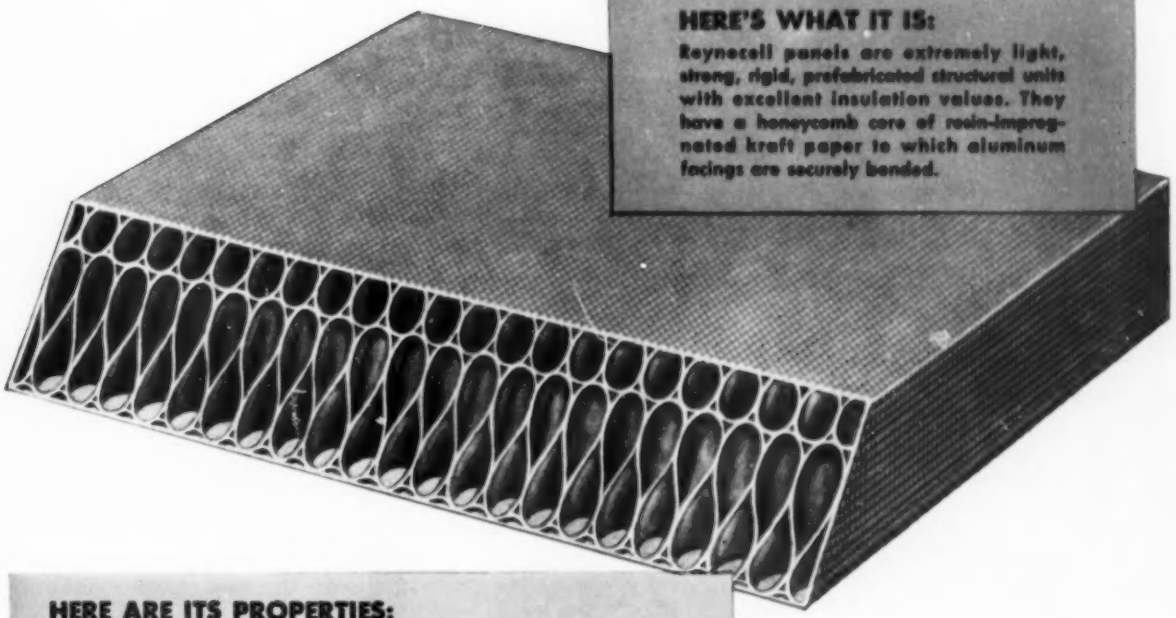
gdc ANTARA

Division of GENERAL DYESTUFF CORPORATION

435 HUDSON STREET . NEW YORK 14, NEW YORK

INTRODUCING

REYNOCELL†



HERE'S WHAT IT IS:

Reynocell panels are extremely light, strong, rigid, prefabricated structural units with excellent insulation values. They have a honeycomb core of resin-impregnated kraft paper to which aluminum facings are securely bonded.

HERE ARE ITS PROPERTIES:

(Typical, based on 4" thick panels. Comparably favorable properties apply to other thicknesses.)

Weight—1.46 lb/sq ft
Bending Strength—180 lb/sq ft of uniformly distributed load on 8' span
Deflection—¼" with 47 lb/sq ft of uniformly distributed load on 8' span
Crushing Strength—70 psi
Thermal Insulation (U factor)—.135
Sound Transmission Loss—31 decibels
Fire and Moisture Resistant—Fungus and Pest Proof

WHERE CAN *YOU* USE IT?

Standard Reynocell panels with .024" stucco embossed aluminum facings are available in sizes up to 4' x 16' with thicknesses from 1" to 4" and with five types of edges. Modifications are possible subject to special inquiry. Reynolds engineers are already working with a number of manufacturers on applications of this amazing new product and are available to assist your designers. Write for more complete information and specifications. Reynolds Metals Company, 2519 So. Third Street, Louisville 1, Kentucky.

† T.M. registered

See "Mister Peepers" Sundays on NBC-TV. Consult local listing for time and station.

REYNOLDS ALUMINUM

MODERN DESIGN HAS ALUMINUM IN MIND

For copper in any form –
For top-notch service –
Call Chase

CHASE

What kind of copper or copper alloy do you need? Free-cutting brass rod? Sheet and strip brass? Phosphor bronze for springs? Call your nearby Chase warehouse. We can supply you with the widest variety of brass or copper materials for production, maintenance or repair.

Many of our branches are equipped to slit, saw, or shear our metals or your own stocks to specifications.

Chase® BRASS & COPPER

WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION

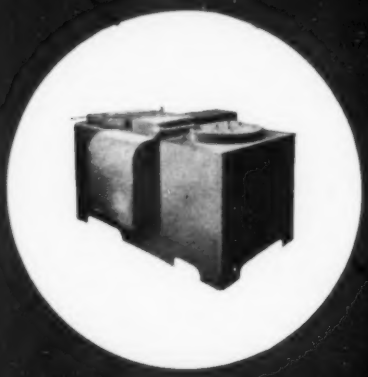
• *The Nation's Headquarters for Brass & Copper*

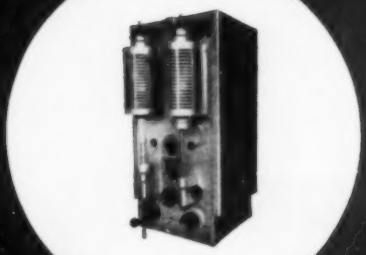
Albany†	Cincinnati	Houston	Minneapolis	Pittsburgh	Seattle
Atlanta	Cleveland	Indianapolis	Newark	Providence	Waterbury
Baltimore	Dallas	Kansas City, Mo.	New Orleans	Rochester†	
Boston	Denver†	Los Angeles	New York	St. Louis	(†sales office
Chicago	Detroit	Milwaukee	Philadelphia	San Francisco	only)

Deliveries to your factory by truck, rail or express, if desired.

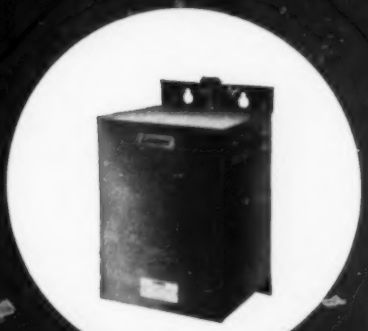
Close tolerance sawing, slitting, shearing to your specifications.

Stocks of tube, rod, bar, strip, sheet and wire in a variety of alloys.





Heat Treating Furnaces...Yes!
and *LINDBERG* also builds..



In addition to heat treating furnaces, Lindberg designs and builds a broad and varied line of related products . . from air cylinders to high frequency induction units.

The story of the complete line of Lindberg products is told in a newly published bulletin. Ask your local Lindberg Man for a copy (#250), or write Lindberg Engineering Company, 2450 West Hubbard St., Chicago, Illinois

LINDBERG FURNACES

What is an Alloy Steel?

This is the first of a series dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Here is an easy definition to remember: An alloy steel is a steel in which one or more alloying elements have been blended to give it special properties that cannot be obtained in carbon steel.

Or, here is the metallurgical definition: An alloy steel is one in which the maximum specified content of alloying elements exceeds one or more of the following limits—

Manganese, 1.65 pct; Silicon, 0.60 pct; Copper, 0.60 pct

or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized commercial field of alloy steels: aluminum, boron, chromium up to 3.99 pct, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other element added to obtain a desired alloying effect.

As a rule, alloy steel is more difficult to make than carbon steel. There are more elements to be kept within specified ranges and, in general, the ranges of the alloying elements are comparatively narrow; hence the mathematical chances for producing off-heats are correspondingly increased. Moreover, most alloy steels require special reheating and cooling to prevent such imperfections as flaking and cracking.

Surface imperfections must be removed from the billets by scarfing, chipping, or grinding. More exacting methods of testing and inspection are necessary to insure uniformity.

WHERE DOES IT PAY TO USE ALLOY STEELS?

Generally speaking, it is advisable to use alloy steel when more strength, ductility, and toughness are required than can be obtained in carbon steel in the section under consideration. Alloy grades should also be used where specific properties such as corrosion-resistance, heat-resistance, and special low-temperature impact values are needed.

In some cases it requires considerable study to determine when and how to use a particular alloy steel to advantage in a product. Where there is any problem or doubt concerning its use, Bethlehem metallurgists will gladly give impartial advice on analysis, heat-treatment, machinability, and expected results.

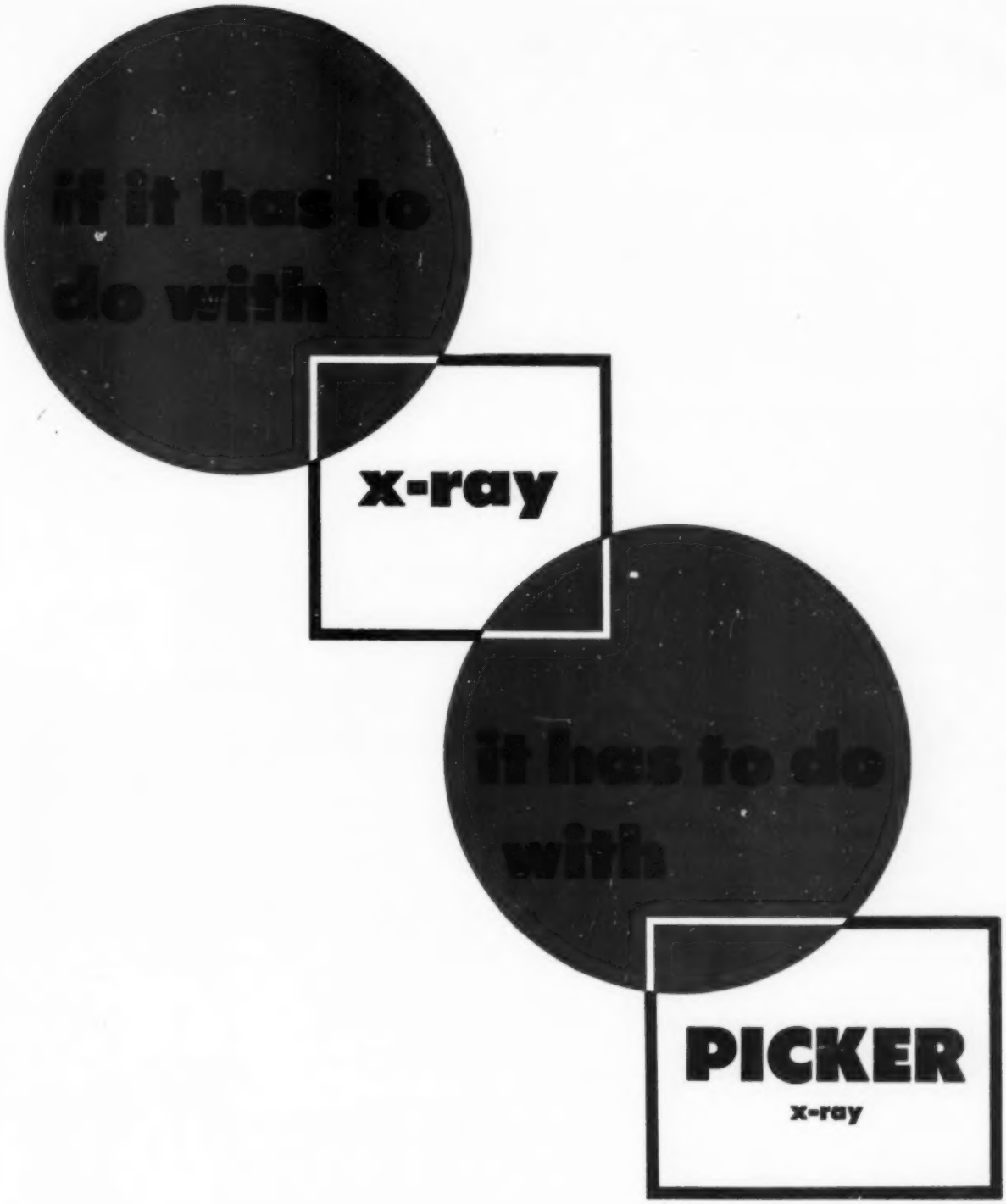
In addition to manufacturing all AISI standard alloy steels, this company produces other than standard analysis steels and the full range of carbon grades.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL



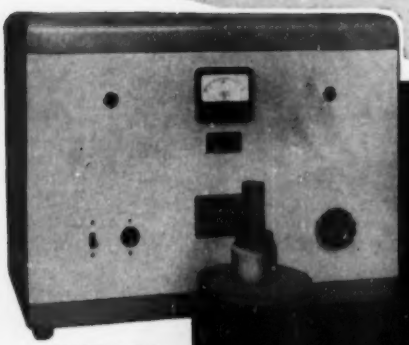
Picker *specializes* in x-ray, and x-ray only, covering the field like a blanket. *Whatever you need, we've got* . . . from a simple lead letter to a 22,000,000 volt betatron. To serve you, there are sales offices and service depots in all principal cities, staffed by skilled engineers prepared to cope with any x-ray problem promptly and with understanding. If you are now using x-ray, or are wondering whether you should, you can depend on Picker for objective technical counsel and efficient handling.

PICKER X-RAY CORPORATION 25 S. Broadway, White Plains, N.Y.
SALES OFFICES AND SERVICE DEPOTS IN PRINCIPAL CITIES OF U.S.A. AND CANADA

Lepel's 3 new

LOW COST - PORTABLE HIGH FREQUENCY *Induction* HEATING UNITS

MODEL T-2½-1
Electronic Tube
Operated
$1620.
f.o.b. factory



MODEL 2 KW
Spark Gap Operated
$870.
f.o.b. factory

Ideal for

- Production Heating of small parts
- Research Laboratories
- Tool Rooms
- Machine Shops
- Educational Institutions

MODEL T-1
Electronic Tube
Operated
$885.
f.o.b. factory

The Lepel line of induction heating units represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for industrial heating. With a background of half a century of pioneering electrical and metallurgical experience, the name Lepel has become the symbol of induction heating equipment embodying the highest standards of engineering achievement, dependable low cost operation and safety.

Amazing in its speed, Lepel equipment reduces the time required for hardening, annealing, stress relieving, brazing, soldering and melting from minutes to seconds. It performs these operations with a degree of precision and uniformity rarely attained through other processes.

LEPEL Electronic Tube GENERATORS available from 1 kw to 100 kw.
LEPEL Spark Gap CONVERTERS available from 2 kw to 30 kw.

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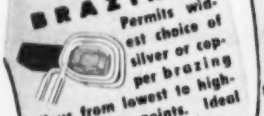

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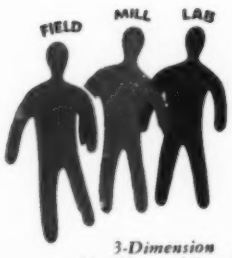

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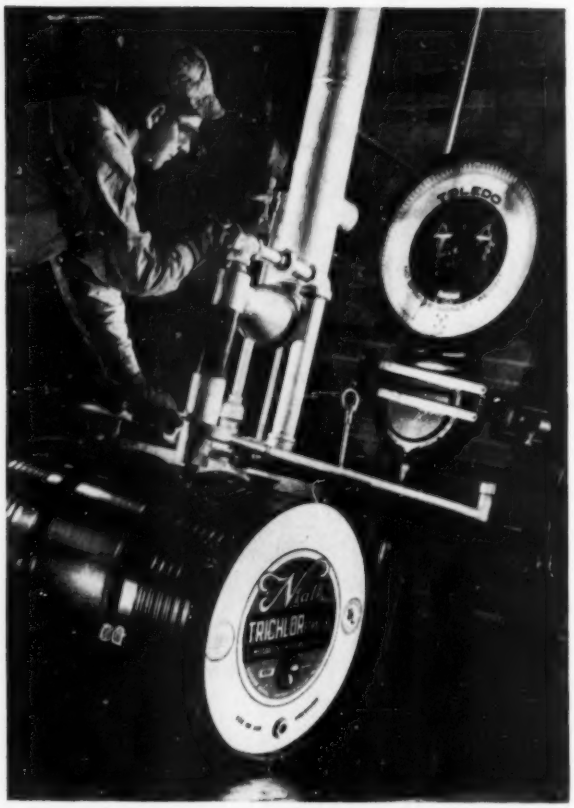

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The Fable

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Figure 1 shows abnormal front clearance wear of a single point tool due to *excessive* chemical activity of the cutting fluid used. The tool failed prematurely, just like the first brother in the fable.

Figure 2 shows abnormal cratering of a tool due to *insufficient* chemical activity of the cutting fluid used. Such cratering is usually associated with poor surface finish. This tool failed prematurely like the indolent brother in the fable.

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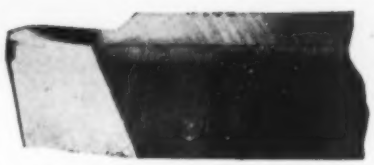

FIG. 1—Abnormal front clearance wear caused by excessive chemical activity of cutting fluid.

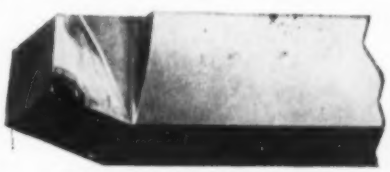

FIG. 2—Cratering of cutting tool, usually associated with poor finish, resulting from insufficient chemical activity of cutting fluid used.

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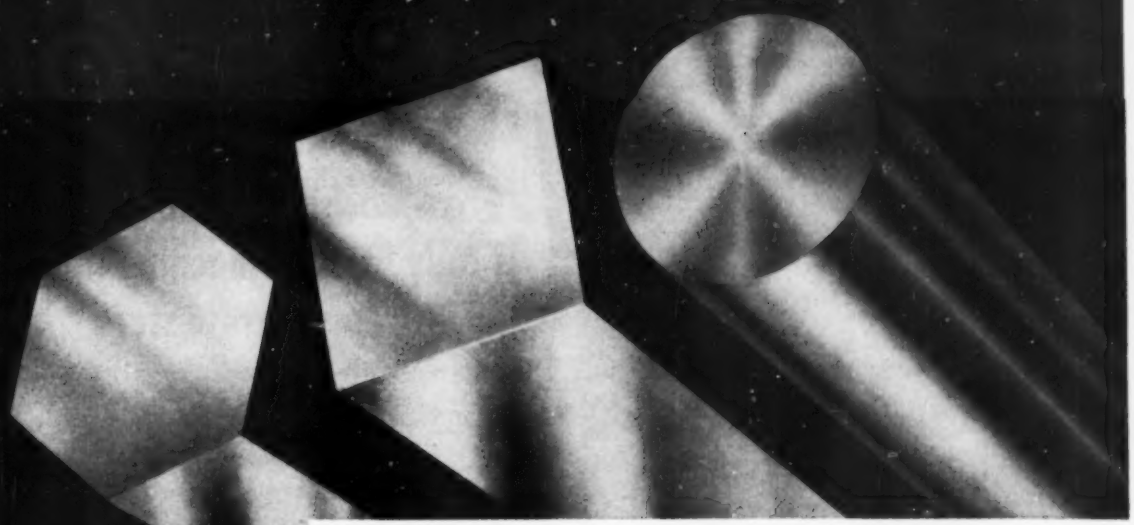

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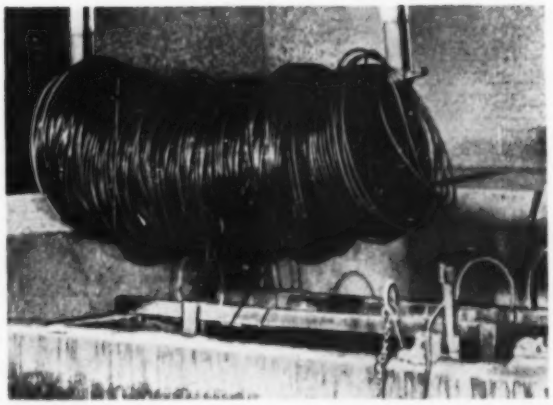

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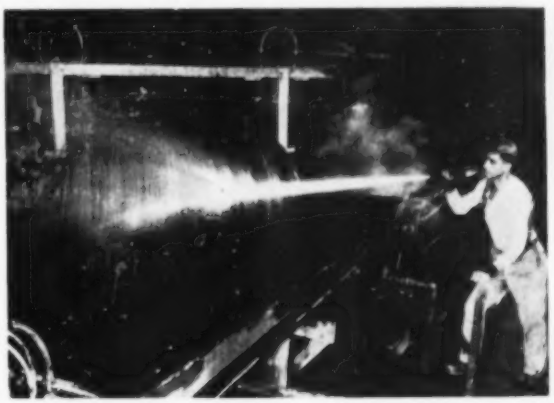

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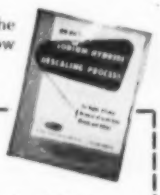

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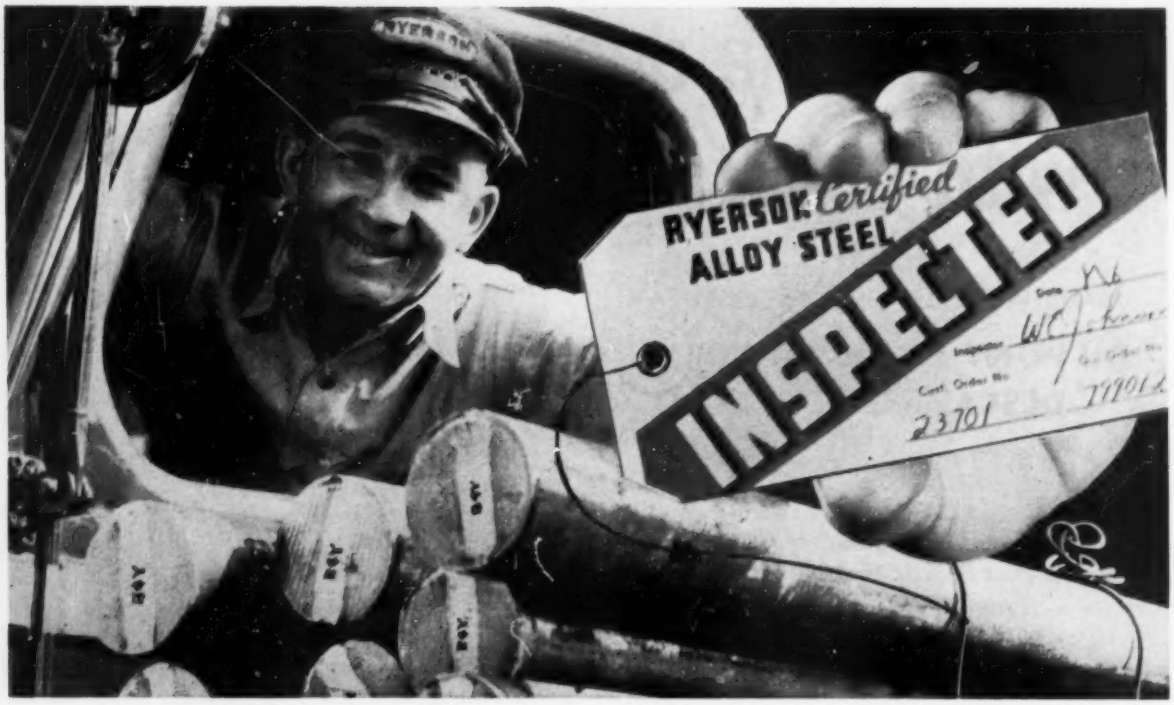

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Forms, Induction Welds and Sizes Thin-Gage Nonferrous Tubing

NONFERROUS TUBING in the past has been produced principally by hot processes as distinguished from cold forming. Hot processes include extrusion, or piercing at high heat and drawing; cold forming involves curling the strip and then electric welding the longitudinal seam, either by localized resistance or induction heat. A limited amount of nonferrous tubing has been made by cold forming and "heliarc" welding, but at rather slow speeds.

Hot forming has held the edge as a favored process because the abrupt melting point of most nonferrous metals has prevented successful welding at speeds high enough to be economical. However, the process and equipment for continuous high-speed cold forming and welding of nonferrous metals in completely integrated tube mills have now been perfected by the Yoder Co. of Cleveland. Several mills of this type have been or are being built. One is installed and operating at Bridgeport Brass Co. in Connecticut; another has been shipped to Kaiser Aluminum & Chemicals Corp., Trentwood, Wash. Two are on order for plants of Aluminum Co. of America, and one for a U.S.

By THOMAS J. CRAWFORD
Consulting Engineer for the Yoder Co.
Berkley, Mich.

Nonferrous Tubing at 120 Ft. per Min.

Naval Ordnance plant. The present nonferrous development was preceded, of course, by Yoder's pioneering work in the design of induction-weld mills for steel pipe and tubing up to about 4 in. in diameter, and running at speeds of 150 to 250 ft. per min.

Induction welding of nonferrous tubing by the new process* is accomplished at speeds of 40 to 120 ft. per min., depending upon gage and diameter, as well as on the type of metal being handled. This is estimated to be from 10 to 30 times faster than previously known methods and compares favorably with the speeds of up to 150 ft. per min. which are used in resistance welding of steel tubing.

The mechanism of induction welding of tubing may be reviewed briefly as follows: High-frequency current is delivered to a short water-cooled inductor coil through which the cold formed tube passes without contact. Induced current travels circumferentially around the tube's surface in the region of the inductor, then flows along the seam edges of the unwelded tube to a nearby point of convergence, substantially beyond the field of induction and close to the centerline of a set of rolls which forces the all-but-molten edges together.

As the current approaches the abutting edges, the "skin effect" as well as the "proximity effect" confines it to a shallow layer on the surface. Practically all the current passes between the edges at the point where the weld is being made. Little or no shunting current passes across the seam beyond this point.

Quality of Welds – Factors of skin effect, proximity effect, and reactance are predominant at the current frequency employed (about 450 kilocycles), thus confining the heat-affected weld zones to an extremely narrow path. Weld zones in tubing made from different grades of aluminum, nickel and other nonferrous metals are uniformly narrow, with grain structures virtually undisturbed by the heat. The photomicrograph at 100× reproduced in Fig. 1 is a typical example of weld zones in aluminum alloys. The exceptionally short time at temperature enables one to touch this weld with bare hands less than 1 sec. after it is made.

Microscopic examination of tubing welded from Type 304 stainless strip likewise revealed uniform grain structure in the weld zone; no carbide precipitation could be seen in areas adjacent to the weld. The joint itself was solid and free from gas holes, porosity, oxides and stress cracks. No evidence was detected of preferential corrosion in samples tested in nitric acid. Tensile tests showed metal in the weld zone to be 15% stronger than the original strip. Two test rings, alternately flattened and opened 12 times, indicated no adverse effects on welds or areas next to them.

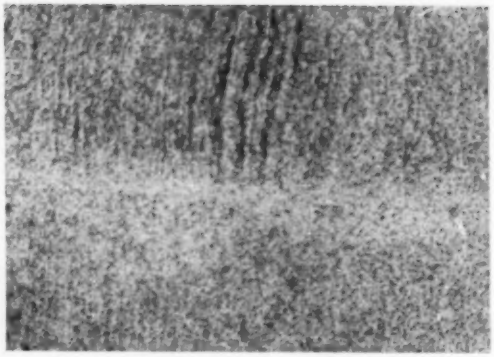


Fig. 1 – Minimum Heat Effect Is Evident in This Micrograph of Weld Zone in 52 S - H 18 Aluminum Alloy Tubing. 50×

Heat is confined to a thin surface layer at the edges to be joined, thereby helping to retain in the finished tubing most of the physical properties acquired through cold working of the strip before welding.

What Metals? – Weldable metals include almost the entire range of aluminum alloys available in coiled strip form; certain magnesium alloys; a wide range of brasses and other copper alloys; nickel and its alloys like Monel and Inconel; austenitic and ferritic stainless steels and the lighter gages of carbon steels. Partially because of high electrical conductivity and absence of a plastic welding range, only limited success on commercially pure copper has been obtained experimentally. For copper alloys and carbon steels, a vapor flux may be used at the point of welding, but no gas or flux is needed with aluminum.

Resistance welded steel tubing is being made in lighter gages than heretofore economically feasible in nonferrous tubing – down to 0.020-in. wall thickness, for example – and with a low limit of 2% on the ratio of wall thickness to diameter. For aluminum, on the other hand, the practical minimum wall thickness made by direct extrusion has been about 0.050 in. – more than double that for steel. This fact has pointed up the desirability of perfecting means of electrically welding aluminum in thinner gages.

Mill Design – Designers of the new mill paid special attention to the techniques of strip

*Patent applications covering process, apparatus and product, now pending, are controlled by the Yoder Co.

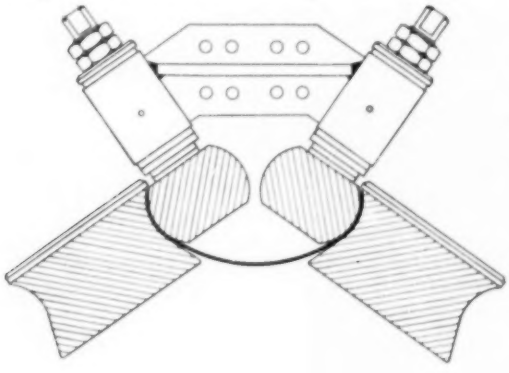
preparation, cold forming and guiding. Ratio of diameter to thickness was brought to a low limit of about 1%, and minimum practical wall thickness to 0.025 in. by modifications in roll design and positioning.

Existing practices and details of equipment for the production of carbon steel tubing were retained to a limited extent. Where they were unsatisfactory, new ideas were explored until a workable solution was reached. The ultimate mill design as a whole, therefore, bears a strong resemblance to Yoder's Type W resistance-weld mills, but differs in details of strip preparation, tooling and forming—and especially in the design of rolls and the means for mounting and adjusting them.

It was expected that the major obstacle in forming light gages would be the tendency of the edges to wrinkle and buckle. Edge buckling is a column failure at the edges of the tube blank, caused by residual compression adjacent to the edges stretched longitudinally in the early forming passes. Due to the nature of the phenomenon, failures, for a given size and gage of tube, are aggravated by an increase in yield strength and a decrease in the modulus of elasticity of the material.

For example, an aluminum alloy, with yield strength comparable to that of carbon steel but with modulus only one-third, should be expected to give trouble in conventional roll forming equipment. When it was attempted to form it into a tube with diameter-to-thickness ratio twice as high as readily made in steel, the edges buckled. The forming problem was complicated further by the need for an adaptable roll setup to handle different metals with yield points ranging from 4000 to 75,000 psi. and a modulus from below 10,000,000 up to 30,000,000 psi.

Fig. 2—Schematic Drawing of 4-Roll Idler Cluster, Focal Point in New System of Nonferrous Tube Forming. Rolls form final radius at edges before the full tube shape is completed



Special Roll Design

Steel tube mills usually contain a series of six or more pairs of driven forming rolls, all revolving in a vertical plane (shafting horizontal) for exerting pressure from both top and bottom. Between each of the first three or four housings (in which the flat strip is formed progressively into an open tube with the gap at the top) idler rolls usually are mounted on vertical spindles to provide side pressure and facilitate entry of the strip into succeeding roll stands. Idler or side rolls do no real work on the partially formed tube. However, in the new process, at least one pair of idler rolls has the important function of edge forming.

Edge forming aims to overcome the inherently greater difficulty of bending the strip at its edges than at the center. In earlier designs for steel tubing the edge areas are curled up in the *first* forming pass to the desired tube radius, while the middle is progressively curved in subsequent passes before the finishing pass.

Control of edge stretch on thin gages in the new process was approached in five ways: (*a*) adjustable lower as well as upper roll spindles; (*b*) generous roll diameters; (*c*) two additional triple-roll idler clusters for the critical vertical transition from the final breakdown pass to the first finishing pass; (*d*) a completely new method of edge forming, and (*e*) correct spacing between successive roll passes.

In forming usual gages of steel strip to tubing shape, the advantages and the disadvantages of adjustable lower roll spindles are about evenly balanced, most operators leaning to the belief that the greater ease of making roll changes and adjustments favors fixed lower spindles. However, for nonferrous tubing, adjustable lower spindles appear essential because of the physical properties of the metals and the high ratio of wall thickness to diameter.

To eliminate edge buckling it was felt that modified edge forming in the first pass, to set a definite radius to the edge areas, would improve column strength. However, the conventional way of doing this in the first forming pass did not give desired results due to the springback in most light-gage materials. Furthermore, the top roll had to be changed for every substantial change in stock thickness.

Figure 2 shows a new system of edge forming which was finally devised. It uses single-radius forming in all the breakdown passes, and does the edge forming in a cluster comprising two pairs of idler rolls after the strip had been first bent longitudinally to a shallow

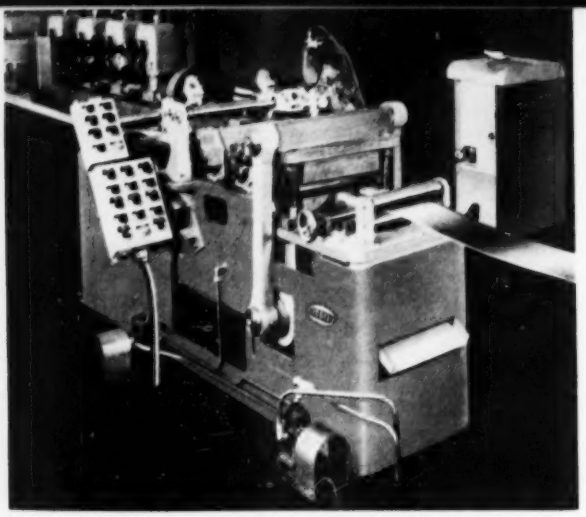


Fig. 3 – Coil Ends Are Trimmed, Clamped and Joined by Inert-Gas Shielded Tungsten-Arc

U-shape in the first two or three driven passes.

The four-roll cluster, it will be noted, operates at an angle and, also unlike conventional idler rolls, does actual forming by applying pressure from both sides of the metal at the edges. The design is readily adjustable to a greater or smaller arc across the strip width, and accommodates a wider range of gages with one single set of small rolls.

Optimum spacing of roll pass centers was found to be critical to avoid giving the converging edges any abrupt change of direction which might cause distortion and excessive residual stresses, leading to buckling.

Illustrations herewith are of the mill built by the Yoder Co. for Bridgeport Brass Co. It is designed to operate at speeds of 40 to 120 ft. per min., depending upon gage and metal. Capacity ranges from ¾ to 4-in. diameter tubing, in wall gages from 0.025 in. up to 0.134 in. This particular mill was designed especially for aluminum and copper alloys of high yield strength and low modulus, to make a wide range of diameters and gages. A further important objective was to utilize the work hardening properties of the non-heat-treatable alloys. One of the newer mills being erected for Alcoa will form and weld tubing up to 8 in. in diameter and in wall thickness up to 0.156 in.

First in line is a conventional strip flattener, then an inert-gas shielded tungsten-arc welder for end-to-end welding of successive coils (Fig. 3). Flattening is a necessary prerequisite to effective arc welding. Welding end-to-end eliminates lost time in threading ends through the mill. The welder has an end-trimming shear and adjustable clamping jaws for strip ends.

Lead end of the strip must be threaded through slowly, with frequent stops through the forming rolls, inductor coil and sizing rolls to get a complete check on functioning before high-speed operation is started. Hence the advantage, where maximum production is scheduled, for either large built-up coils or a looping arrangement for continuous feed at full speed.

The forming mill, Fig. 4, includes an entry table equipped with felt wipers, pull-over-pull-under rollers, tungsten carbide-faced side guides and a pair of adjustable edge trim cutter holders to insure exact stock width and clean, smooth edges. The first driven roll stand (at the right end of the foundation bed) has flat feed rolls for pulling the stock through the edge trimmer. This is followed by three driven roll stands, each one separated from its neighbor 18 to 20 in. clear, and mounting breakdown rolls which, in combination with idler rolls between and beyond the stands, completely form the strip to approximately tubular shape, with a gap left between the edges at the top.

The first set of idler rolls is of conventional design. The second set, between the second and third breakdown rolls, is the diagonally mounted combination shown in Fig. 2. Two pairs of triple-roll idler clusters are set between the third driven roll stand and the first finish pass. The three finish-pass roll stands are close-coupled in a single housing just to the right of the control board of Fig. 4.

Fig. 5 is the welder unit comprising, from right to left, a seam guide and spreader blade with a three-roll cluster of idler rolls and the inductor coil which induces welding current in the tube blank.

Fig. 4 – Complete Tube Forming and Welding Mill for Handling Aluminum Alloys Down to 0.025-In. Wall Thickness, in Diameters of ¾ to 4 in., and at Speeds of 40 to 120 Ft. per Min. Strip enters from right into flat pinch rolls, three individual forming roll stands, then a cluster of three finishing rolls, through the induction welder (behind control desk), and on to sizing rolls

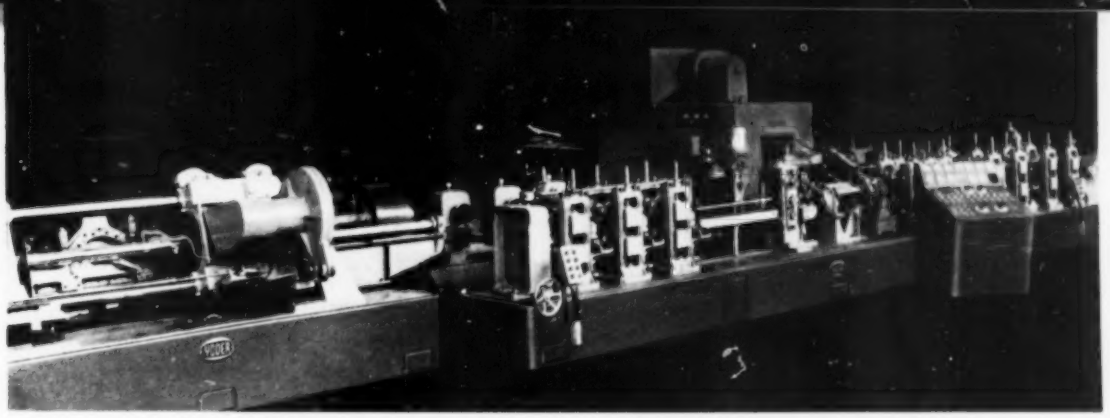


Fig. 6 – Exit Side of High-Speed Tube Welding Mill. Tubing from three sizing roll stands (center) advances through automatic cutoff saw at extreme left. Sizing section (center) includes three driven and three idler roll sets, followed by a universal straightener

Squeeze rolls are key elements in welding. The ones in this mill are of a new design and include a holder for the three-roll cluster, each roll (and the cluster as a unit) being adjustable to obtain correct pressure through operation of a star wheel. Pressure is measured by a strain gage on one of the roll mounting arms.

Outside welding burr or flash trimmer, as well as the ironing rolls of Fig. 6 which follow, is of standard design. Where tube size permits, a mandrel can be used to trim off the inside flash.

A short cooling section is provided between the welding unit and the sizing mill. The latter, Fig. 6, comprises three driven and three idler roll stands, with a universal straightener at the exit end. They are also of standard design, with tooling substantially the same as used on resistance-weld mills for steel tubing. A flying cutoff saw has been incorporated in the Bridgeport layout, although other means of automatic cutoff might be employed, such as a shear-type press or rotary machine, both extensively used in steel tubing mills.

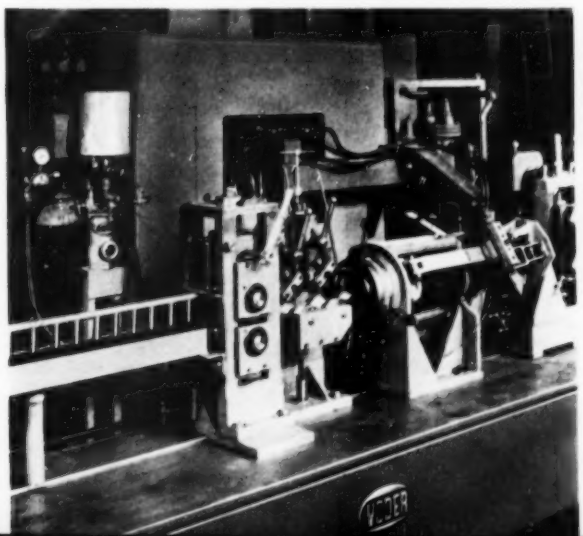
The mill drive includes a variable-voltage generator, excited by a magnetic amplifier which compares forming mill tachometer voltage with a reference voltage, and holds speed within 0.5% of the pre-set value. A 50-kw. welding oscillator unit takes power for its plate rectifier from a 100-kva., three-phase alternator set, designed to eliminate effects of supply line variations. The alternator likewise is excited by a magnetic amplifier which maintains the plate voltage of the oscillator at any level that may be desired.

Product – Typical samples of nonferrous induction-welded tubing after tests to determine weld strength (no failures resulting) are shown in the photograph at the head of this article, p. 65. In the center foreground is a piece of pure nickel tubing; grouped around it, from left to right, are 70-30 brass, 52S-H32 aluminum alloy, low-carbon steel and B50S-H32 aluminum.

In addition to conventional types of aluminum tubing, this process is suited to production of aluminum-sheathed cable. Cable and aluminum strip can be fed simultaneously into the mill and the sheath continuously formed and welded around the cable at high speed.

Cable sheathing of aluminum alloy, already widely used in England and Germany, has been fairly recently introduced in the United States, but appears to have a good future. Being 75% lighter than lead, six times stronger and seven times as hard, it has obvious advantages where the characteristic corrosion resistance of lead is unnecessary in telephone, power line, bridge and aerial cables, particularly those in which internal pressure is used and where vibration is a factor. The sheathing passes through the welder so fast and the heat is so quickly dissipated that no damage results to a paper-wrapped inside cable—yet a water and gas-tight weld is achieved.

Fig. 5 – Closeup of Induction Welding Station, with 50-Kw. Oscillator at Rear. A short inductor coil is held on an arm extending from the housing between spreader blade and squeeze rolls at extreme right of view. Moving from right to left, welded tubing passes under tandem flash cutters at center of view, through support rolls and onto train shown in Fig. 6



ectrical Steel— a Triumph of Steelmaking, Heat Treatment Scientific Metallurgy*

By WILLIAM JONES, Administrative Assistant to Manager of Sales Division
Armco Steel Corp., Middletown, Ohio

WITH THE RISE of the electric industry, especially the growth of alternating current for the transmission of power, three basic materials became necessary. These are copper to provide a path for the electricity, insulation to confine it to that path, and iron to provide the magnetic field necessary to convert mechanical to electrical energy and vice versa. Of these three, the iron is the least replaceable. Aluminum can be used in place of copper; there are a variety of synthetic insulations; but no satisfactory economical substitute exists for iron in magnetic core construction.

I shall therefore discuss tonight the iron-silicon alloys, which are by far the most important of all the magnetic materials. Being very low in carbon they are really "silicon irons", but they are universally miscalled "silicon steels" in the trade. 750,000 tons per year are consumed by the rapidly growing American industry, so it has considerable stature in the field of specialty steels and irons.

Early transformer cores of the 1880-1890 decade were made of sheet iron or steel laminations, but they heated badly due to high eddy current losses. Worse, they deteriorated badly with use – they "aged". A byproduct of Sir Robert Hadfield's search for abrasion resistant steels was a silicon-iron alloy which was found to make a superior transformer core for three reasons as follows:

1. The alloy was well deoxidized and the hysteresis loss was reduced.
2. The alloy had higher electrical resistivity and lower eddy current losses.
3. The alloy was practically nonaging.

Since the turn of the century, continuous developments eliminated loose scale with an attendant gain in lamination stacking factor, flat sheets provided more compact cores, applied insulations diminished inter-lamination losses, and coils reduced end-of-the-sheet scrap. During this period the total core loss was reduced to 25% of that obtainable from the

*Portions of address before joint session, Oct. 15, 1953, of St. Louis Chapter [illegible], St. Louis Section of American Society for Testing Materials, and the Engineer's Club of St. Louis.

steels available prior to the Hadfield discovery.

However, during this period of the development of the hot rolled transformer sheet one desirable property proved to be most elusive. This was permeability, or ease of excitation at high induction. As a matter of fact, the lower the core loss, the greater the deterioration in permeability.

This impasse between core loss and permeability was finally solved early in the 1930's by Norman P. Goss. Again an important development in magnetic core material was the result of an experiment designed to obtain entirely different results. Goss was employed by Cold Metal Products Co. of Youngstown, Ohio, to determine if silicon steel could be produced in continuous coils on a Steckel reversing cold mill. The limitations of the mill and the work hardening of the material required an anneal between passes. It happened that this series of cold reductions and intermediate annealings resulted in remarkable improvement *in the rolling direction.* Not only were the losses much lower than in hot rolled silicon steel sheets, but an improvement in permeability was also noted. The old barrier of excitation limitations was removed!

Thus was born what has become known as oriented electrical steel in which the crystals have been so lined up that their axes of easiest magnetization are nearly parallel. The discovery of Norman Goss provided but a clue to future developments. We at Armco went through a period of five years of intensive research to determine suitable methods of commercial manufacture.*

The first major obstacle to be overcome was poor ductility. The addition of silicon to iron results in an alloy which is much more difficult to roll than low-carbon steels, especially when cold. The hazard in hot rolling is not so great.

*Work along this line done by General Electric Co. and Allegheny Ludlum Steel Corp. has been outlined by Weston Morrill in an article entitled "Improved Silicon Irons for Electrical Equipment" in *Metal Progress* for November 1948, p. 675. Crystals 90% aligned within a 10° cone represent the commercial result.

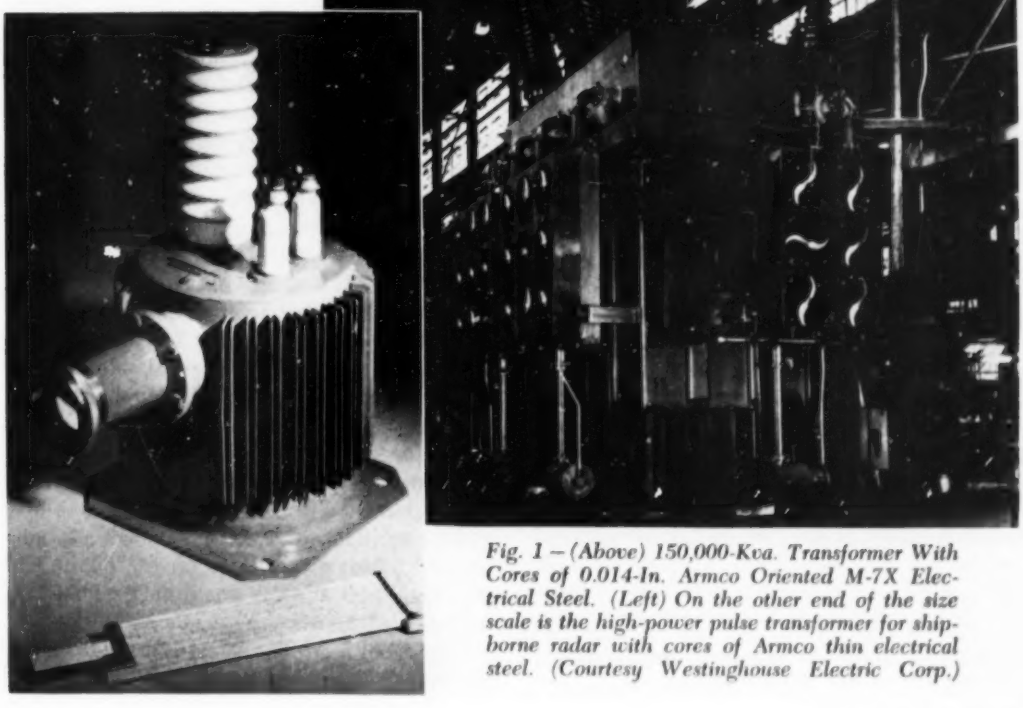


Fig. 1 – (Above) 150,000-Kva. Transformer With Cores of 0.014-In. Armco Oriented M-7X Electrical Steel. (Left) On the other end of the size scale is the high-power pulse transformer for shipborne radar with cores of Armco thin electrical steel. (Courtesy Westinghouse Electric Corp.)

Processing Silicon Steels

Next a proper program of reduction ratios and intermediate annealings had to be worked out for full development of preferred orientation in the final anneal. A suitable analysis had also to be selected, as well as means to produce it and maintain it.

An improved surface insulation had also to be devised due to the fact that oriented electrical sheet is strain-sensitive and, therefore, must be stress-relieved at 1475° F. after the fabrication of the core. Organic varnishes burn off at this temperature. Armco developed "Carlite Insulation" – a chemical and thermal treatment resulting in an insulated surface unaffected by the stress-relief anneal. Due to its extreme thinness it changes almost imperceptibly the lamination stacking factor.

With these basic problems solved, there became available an entirely new type of magnetic core material with core loss of less than 1.00 watt per lb. at 15 kilogausses. Further improvements have reduced this limit, first to 0.90, then 0.80 and finally three-quarters of the present production of 0.014-in. sheet meets a limit of 0.73.

Concurrently came the production in coils of the more conventional medium-silicon and low-silicon grades. This, too, was an important advance in the art, for it permitted high-speed automatic production of punched laminations and eliminated end-of-the-sheet scrap. Two forms of coils are now available: Sheets butt welded end to end are satisfactory for punched and sheared laminations and are available in all hot rolled grades of electrical steel. Coils produced by the cold reduction process are limited to the low and medium-silicon grades.

The principal ingredients needed in the manufacture of silicon steel are *(a)* analysis, *(b)* processing facilities and *(c)* technique.

Analysis – The entire series embraces a range of from 1.0 to 5.0% silicon with the balance essentially iron. Melting and pouring practice must be of the highest type to help provide uniformity of magnetic properties and freedom from physical defects.

Rolling – Conversion from 0.350-in. sheet bars, 0.109-in. thin bars or 0.100-in. hot rolled coils to finished gage is done on equipment used on other grades of steel. Sheet bars are reduced on the old style two-stand, two-high hot mill. Three-high mechanized hot mills with continuous heating furnaces are used for 0.109-in. thin bars. Hot rolled coils are cold reduced as thin as possible on continuous tandem mills, and further on reversing four-high cold mills.

Heat Treating – Following reduction to final gage, the processing equipment is specialized and consists of box and continuous type annealing furnaces, electrically heated and thermally and atmospherically controlled to close limits. Pickling tanks with special acids are needed to clean the highly resistant silicon alloy. Welding equipment butt welds the light-gage sheets without objectionable welts. Special coating equipment applies surface insulation.

Testing – Lastly is the highly specialized testing equipment for magnetic and mechanical characteristics. Probably more testing is done on a silicon grade than any other grade of steel. At least a half million Epstein core-loss samples are tested annually.

Technique – Of the three ingredients mentioned previously, the third is the most important and most difficult to acquire. We are dealing not only with an alloy inherently brittle and difficult to manipulate, but there is always present a mysterious and elusive element known as magnetism concerning the nature of which we have but little fundamental information. The development of silicon-iron alloys has been very much on the empirical side; in fact, the two basic discoveries were purely accidental.

Such a product requires a manufacturing organization trained through the years and backed up by a corps of observers carefully watching all critical points of manufacture and ever on the alert for new apparatus – mechanical, thermal and electronic – to record the manufacturing conditions. Statistical analysis of such records provides valuable clues to further development. Perfection never has been achieved, and never will, for new standards are always being set.

In the industry, the principal silicon steels are classified as *(a)* low-silicon, *(b)* medium-silicon, *(c)* high-silicon, *(d)* oriented, *(e)* hot rolled, *(f)* cold rolled.* The A.I.S.I. type numbers divided by 100 roughly approximate the 15-kilogauss core loss limit for 29-gage sheet (0.014 in. thick).

The low-silicon group is comprised of Types M-43 and M-36, with silicon contents approximately 1.0 and 1.5%. They are usually required in 24 gage (0.025 in.), and are available in coils or cut-lengths with widths up to 36 in. The principal application is small motors for intermittent-duty household appliances.

Types M-27, M-22 and M-19 make up the medium-silicon group with approximately 2.5,

*See American Iron & Steel Institute's "Steel Products Manual", Section 26, on Flat Rolled Electrical Steel.

3.0 and 3.5% Si respectively. They are manufactured in 24, 26 and some 29-gage thicknesses and are available in coils and cut-lengths up to 36 in. wide. These grades are widely used in refrigerator compressor motors, industrial motors, and television and radio transformers.

The high-silicon group consists of M-17, M-15 and M-14 with silicon contents in the range of 4 to 5%. They are manufactured only by the hot rolling process, usually 29 gage (0.014 in. thick) and are available in welded coils or cut-lengths up to 32 in. wide. These have low core loss and are designed principally for power transformers and generators. Until the introduction of oriented grades, high silicon iron was the only material suitable for these applications.

COMMERCIAL ORIENTED TYPES

Although no A.I.S.I. type numbers have been officially assigned to the oriented classification, we may, for the sake of consistency, state that M-8, M-7 and M-6 make up the group of oriented types. These correspond to sheet having core losses of 0.80, 0.73 and 0.64 watt per lb. at 15 kilogausses. Inasmuch as oriented grades are cold rolled, silicon is limited to about two thirds that of the best hot rolled transformer grades. Notwithstanding the low silicon, the preferred orientation reduces hysteresis losses to the extent that they more than offset the increased eddy losses due to the lower silicon content. The result is a total core loss, when tested in the direction of orientation and at 15 kilogausses, almost half that of the best grades of hot rolled transformer sheets. Along with low core loss is high permeability, a combination permitting transformers to operate at higher inductions without excessive excitation.

Oriented types are manufactured in 0.014 and 0.012-in. thicknesses and normally are furnished in coils up to about 30 in. wide. The thicker sheet is used generally in power transformers where the laminations are stacked flat. The thinner sheet is particularly designed for "wound-core" distribution transformers. Currently, some manufacturers of large generators are using the 0.014-in. oriented type.

The great advantage of oriented over hot rolled transformer sheets lies in the fact that the cores of oriented sheet can be operated at higher inductions. This means that equal electrical characteristics can be obtained with smaller cores. Varied opinions can be secured in respect to the material savings thus obtained, but the consensus is about as shown alongside.

Magnetic Requirements of Electrical Steel

The increased cost of oriented over the best grade of hot rolled transformer steel is just about offset by the smaller amount of core steel required. The manufacturer therefore gains the savings in structural and tank steel, copper, insulation and oil, although these savings are partially reduced due to the unusual care and treatment required in the fabrication and assembly of oriented laminations.

NOTES FOR USERS

Now a word or two about the characteristics of interest to the buyer of silicon sheet.

Magnetic Properties – Many and varied are the magnetic requirements, but of top importance commercially is core loss under alternating current magnetization. Low core loss keeps heat losses low. All standard grades are made to strict specifications in this respect. The general rule for hot rolled sheet is that the higher the silicon and the thinner the sheet, the lower the core loss.

Another magnetic characteristic, not generally used in commercial grading, is permeability. In hot rolled grades, this is inversely proportional to silicon content at high inductions. So, the designer is on the horns of a dilemma. If the equipment operates at a high induction, he must sacrifice permeability to get low core loss – or, if high permeability is a requisite, he must be content with a higher core loss than desirable. The inevitable result is a compromise unless he uses oriented sheet.

Fabrication – Silicon steel laminations are varied in shape. They may be complicated toothed circles as in motors and meters, or rectangular as in transformer I-plates. In between are the E and I shapes used in television and radio transformers.

Fabrication is either by shearing or punching. Shearing presents no problem other than keeping the blades sharp to avoid burrs. Sometimes the 4.5 to 5% silicon grades become extremely brittle, particularly when cold, but a warming to 200° F. will eliminate breakage.

Punching of silicon sheet laminations in costly dies is an inexhaustible subject, and for many years has been a bone of contention between supplier and user. The user blamed the steel

	Core Steel	Structural Steel	Copper
Large power transformers	15%	10%	10%
Small power transformers	20	15	13
Distribution transformers	25	20	25

and the supplier blamed the die. Probably both were right. Ten or 12 years ago, when atmospheric controlled, continuous annealing furnaces produced improved surfaces, fabricators started using carbide dies. This combination of improvements jumped die runs immediately from 50,000 strikes per die grind to a million. The furor has now subsided—at least until five million strikes per grind become necessary!

Stacking factor or space factor is of considerable importance. It is the percentage by weight of a stack of laminations within a given volume, as compared to the weight of the same volume of solid steel. In general, stacking factor is related to the surface smoothness of the steel, although it is obvious that edge burr and flatness are also important factors. The smooth surface of cold reduced steels results in higher stacking factors than with hot rolled, although four-high temper rolling of hot rolled grades approaches it very closely.

In stacking a magnetic core structure, the very best lamination flatness is needed. The reason is two-fold: Unflat laminations result in a less magnetically active core within the copper coil, resulting in higher operating induction under a given magnetizing current and consequent greater core losses and decreased permeability. Unflat laminations also cause springy cores which, when riveted or bolted, become highly strained, and strain seriously affects the magnetic properties.

The lack of flatness in laminations can be traced to wavy steel, to faulty punching or shearing practice and to improper handling during assembly. During the past 25 years, much improvement has been obtained in the flatness through the use of mechanized hot mills, continuous cold mills and modernized annealing equipment. Widespread recent practice of annealing after stamping removes the distortions of fabrication.

Surface Insulation – As steel grades go, silicon sheets are very thin, being confined principally to 24, 26 and 29 gages. (0.025 to 0.014 in.) Light gages reduce the eddy current losses. But thin steel is of no avail unless the laminations are electrically insulated from each other.

In some instances, particularly if the equipment is small, adequate insulation is secured from the oxide formed during annealing. In others an applied insulation is required. Until ten years ago, applied insulations were organic in nature and deteriorated during the stress-relief anneal necessary for oriented electrical steel. A combination of chemical and thermal treatment was developed which produced a very thin insulation, with negligible reduction of stacking factor, and one that successfully resists deterioration up to 1500° F.

RECENT DEVELOPMENTS

And now perhaps a few words about more recent developments of ultra-thin electrical sheet may be of interest. Early in World War II the then new radar equipment became a most important tool of modern warfare in the air. A race was on to determine which side, Allied or German, could produce radar of shortest wave length. The winner could jam the waves of the opposition without damage to his own equipment. A prime essential for shorter wave equipment was thinner silicon steel. Five-mil (0.005-in.) material (about one third the thickness of conventional 29-gage sheet) had been made on standard mills but the goal was set at 2 mils. Because of its familiarity with oriented grades, Armco installed in its research laboratories a Sendzimir mill specially designed to produce the 2-mil oriented silicon steels which formed the cores of vastly superior radar equipment. (Two mils is 0.002 in., about half the thickness of the sheet of paper this is printed on.) During World War II the production unit in the laboratories, under laboratory control, was the sole source in this country.

Since the end of World War II there has been a tremendous surge in electronic development with increasing need for thin electrical steels. Production units are now in the mill for commercial tonnages in thicknesses of one mil.

More recent magnetic amplifiers for digital computers need even thinner materials. Again a special unit now has been set up in the Armco laboratories producing nickel alloys as thin as ¼ mil. We refer to this as our "single side strip"! One pound, ¾ in. wide, is 4 miles long, and it sells at $4,000,000 per ton. Only the youngest of our organization ever expects to see a ton made, for it would be sufficient to make 160 million cores for computers.

Of course there are other special magnetic alloys, but with the exception of pure iron they are extremely high priced. Nothing as yet has appeared on the horizon to challenge the position silicon steel has held in the electrical industry over the past 50 years. This alloy seems destined to go forward with an industry assured, as long as civilization exists and mankind seeks ways of doing things easier, of a continuously expanding progress.

Effective Heat Treatment of Molybdenum

By T. G. PERRY
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time of annealing, the strain rate and annealing atmosphere employed. It is the purpose of this note to relate such behavior to the nature and distribution of residual oxygen in the metal.

Metallographic or fractographic examination of industrial unannealed molybdenum wire does not usually reveal the presence of residual oxide inclusions. It is necessary to conclude that, aside from the presence of an occasional large inclusion, the process of working distributes any undissolved oxygen in extremely fine particles. The mechanical anisotropy of molybdenum wire and sheet is related to the distribution of such undissolved oxygen.

IN SPITE OF the progress made in the development of cermets and ceramic components for applications above 1500° F., the many advantages of molybdenum for such use should not be neglected. To be sure, no successful protection against "catastrophic oxidation" and no simple all-purpose method of producing ductile joints have as yet been reported in the technical literature. Nevertheless, research is still being carried on in this field and answers to these problems should ultimately be provided. In our own laboratory, we have been greatly interested in the way commercial wrought molybdenum is embrittled by heat treatment, and some of our recent results are incorporated in this paper.

It is well known that wrought molybdenum possesses considerable ductility at room temperature, but that cast or sintered bar stock invariably exhibits no tensile ductility at room temperature. Wrought molybdenum annealed between its recrystallization temperature and its melting point can exhibit ductile or brittle behavior depending on the temperature and

Wrought molybdenum parts made by powder metallurgy, when annealed above the recrystallization temperature but below about 3540° F., show no undissolved oxygen. Even though primary recrystallization has taken place, J. H. Bechtold points out that no grain growth occurs in this temperature range unless sufficient carbon content is present (Research Report R-94402-18-I, Westinghouse Research Laboratory, 1952). J. P. Altorffer, in his 1949 M.I.T. thesis, has shown that at room temperature the tensile ductility of annealed fine-grained material is high immediately following recrystallization, but decreases rapidly with annealing time at temperatures below 3540° F. to less than that of wrought metal. Molybdenum that has been annealed below 3540° F. and fractured below room temperature, exhibits predominantly transcrystalline failure. If

*Mr. Perry was formerly research assistant at M.I.T., Mr. Spacil is instructor, and Dr. Wulff is professor of metallurgy. The experimental facts described in this paper are the result of research sponsored at the Massachusetts Institute of Technology in part by the Air Force and in part by the Oak Ridge National Laboratory.

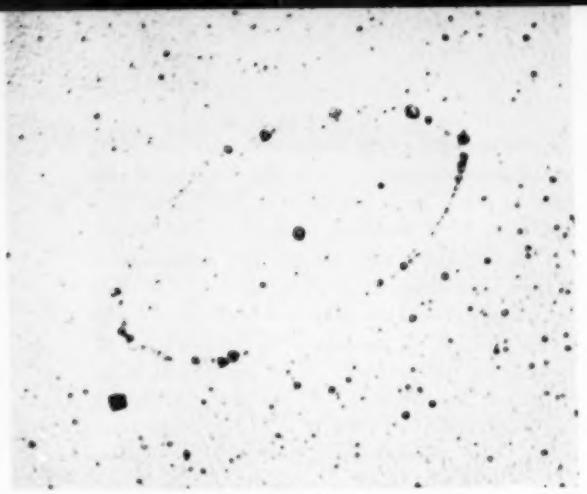


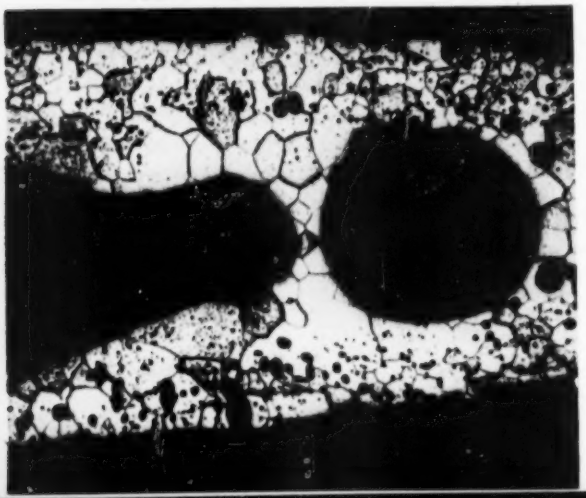
Fig. 1 – Inclusions Left Within a Single Grain on Holding for 1 Hr. at 3685° F. Lightly etched. 1000×

gaseous oxygen is present in the annealing atmosphere, polycrystalline material becomes brittle at room temperature and failure originates more often at grain boundaries; single crystals do not behave in this way, according to R. Maddin.

Annealing between about 3540 and 3850° F. produces visible spheroidal oxide inclusions. Figure 1 shows these inclusions both in a former grain boundary (more or less oval in shape) and in the interior of a grain. In this temperature range, grain growth can be rapid, and large single crystals can be grown from wrought material ("Plasticity of Molybdenum Single Crystals," by N. K. Chen and R. Maddin, *Transactions* A.I.M.E., Vol. 191, 1951, p. 937). Such annealed material possesses high tensile ductility at room temperature unless a single large grain boundary in the test section is oriented normal to the applied tensile stress. Except under the latter condition, fracture is again predominantly transcrystalline.

Annealing above about 3850° F. forms intergranular oxide precipitates. These appear as chevrons in intercrystalline fractures of cast material of low oxygen content (approximately

Fig. 2 – Porosity Induced in 1/16-In. Wire by Heating to 4500° F., Etched. 30×



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0.001%), as nearly continuous films in cast material of high oxygen content (0.01%), and as a dense population of chevrons in annealed wrought commercial material. In general, no grain growth takes place above 3850° F. and tensile ductility at room temperature after annealing is too low to measure. Rapid heating into this temperature range, particularly to just below the melting point of molybdenum, produces voids in the material, sometimes with explosive violence. Figure 2 illustrates such voids produced at 4500° F. in a drawn molybdenum wire which was heated rapidly in purified helium. The room-temperature mechanical properties of material in such a porous condition are obviously very poor.

In view of other experiments, the voids described above cannot be ascribed simply to occluded gases. A more reasonable explanation for their formation is the evolution of molybdenum trioxide vapor from solid molybdenum dioxide according to the reaction:

$$3\ MoO_2 \rightarrow 2\ MoO_3\ (gas) + Mo.$$

Thermodynamic calculations in T. G. Perry's 1953 thesis indicate that the vapor pressure of MoO_3 vapor over solid MoO_2 and Mo is greater than one atmosphere above 3800° F. Because of the low strength of molydenum at temperatures near the melting point, the trioxide vapor readily forms voids.

If such MoO_3 vapor does not produce sizable defects in the structure above 3800° F., another reaction occurs which also impairs the intergranular strength of the material. This reaction is the eutectic melting of molybdenum and molybdenum dioxide, which occurs just above 3850° F., as shown by auxiliary experiments. Liquid produced by this reaction readily wets molybdenum and spreads in the grain boundaries, thus inhibiting grain growth. This eutectic liquid also leads to the low tensile properties at room temperature of commercial wrought molybdenum by solidifying as a grain-boundary precipitate after annealing above 3850° F. Figure 3 indicates how MoO_2 heated in contact with molybdenum at 3900° F. alloys with the solid metal.

The highly ductile material found after annealing in the range 3540 to 3850° F. probably owes its mechanical properties to the shape and discontinuous nature of the spheroids of molybdenum dioxide shown in Fig. 1. Since such spheroids do not form below about 3540° F. in carbon-free molybdenum, the residual oxide

must be distributed in some submicroscopic angular form which is stable because of the free energy relationships between the metal and the oxide. The lack of grain growth below 3540° F. can be attributed to the presence of submicroscopic oxides at grain boundaries; such fine precipitates need not necessarily lead to intercrystalline fracture. Introduction of further oxygen from the annealing atmosphere can embrittle the grain boundaries by increasing the extent of grain-boundary oxide. Since this does not happen to single crystals, oxygen solubility must be extremely low and grain-boundary diffusion extremely rapid.

Fig. 3 – Etched Section of MoO_2 Heated in Contact With Mo at 3900° F. Black regions are unresolved MoO_2-Mo eutectic stucture rich in MoO_2; it is evident that the eutectic has melted and penetrated the grain boundaries. 750×

APPLICATION TO WELDING PROCESSES

The experimental results described are not only of interest to the practical heat treater of molybdenum, but are also of importance to those interested in joining. Thus, simultaneous hot working and joining should heal voids produced by boiling trioxide, and should properly distribute grain-boundary dioxide precipitates whether resulting from oxygen contained in the molybdenum or in the joining atmosphere. This is exactly what was recently accomplished by J. H. Johnston and J. Wulff in making ductile butt welds in commercial molybdenum ("Molybdenum Welding", WADC Technical Report No. 53-260, July 1953). The same viewpoint deserves more attention in spot welding and brazing. Where joints cannot be made by simultaneous application of pressure and heat, post hot working merits attention.

Economic Survey of Seven Methods of Making Small Machine Parts

By SAMUEL STORCHHEIM, Engineer in Charge, Atomic Energy Division
Sylvania Electric Products Inc., Bayside, N. Y.

THE ENGINEER contemplating the use of small machine parts has to consider three factors: (*a*) the functional purpose of the part, (*b*) the physical qualities of the material, (*c*) the methods which can be used to manufacture the part. The choice of manufacturing is determined by (*a*) production cost, (*b*) production speed, (*c*) necessary tolerances, and (*d*) appearance.

The term "small parts" is used here for those not heavier than approximately 10 lb. and not larger in any dimension than about 6 in. These small products may be made by 15 or 20 different methods. In this article the six most important of these manufacturing methods are compared with the powder metallurgy method in a manner analogous to that which a machine parts designer might use for comparison.

Permanent mold casting (gravity die casting) involves pouring of the molten metal under a gravity head into molds made of metal. The materials cast are aluminum or magnesium alloys, bronzes, cast iron, zinc and lead. The

raw materials, especially iron, are fairly cheap. Die costs are moderate and almost always less than for die casting and powder metallurgy. Direct labor costs are fairly low, and finishing is not expensive since very little machining is needed. It takes several days to a few weeks to get into production with permanent mold casting. Output is moderate – seldom greater than 50 to 80 pieces per hour. The maximum size of permanent molded pieces is less than 50 lb. (of aluminum). Precision for the permanent mold process is high, with tolerances ranging between ± 0.0015 and 0.010 in.

Die casting involves injecting or transferring under pressure the correct quantity of molten metal in a water-cooled metal die set. The set remains closed until the casting has solidified. Fast working machines to perform these operations fall into three categories:

1. Cold-chamber machines, in which an injector ram is located in the cylinder. Molten metal is ladled into the ram and is then injected into the die at 500 to 2000 psi. pressure. Usually magnesium, copper and aluminum alloys are used in these machines.

2. Direct air injection machines (better known as "gooseneck"). Molten metal, held in a pot, is subjected to air pressure, which forces the metal through a gooseneck outlet into the die. These machines are used primarily for casting aluminum alloys and operate at 500 to 600 psi. pressure.

3. Plunger Machines. A cylinder immersed in the molten metal, usually a zinc alloy, injects it into the die. The cylinder is motivated by either air or hydraulic pressure, ranging from 1500 to 3000 psi. for these units.

Raw material costs for die casting are medium, but die costs are higher than for other casting methods, ranging between $500 and $3000. The direct labor costs are medium to low, and finishing costs are low, since usually no machining is needed. It takes a few weeks to get into production with die casting. Output is very high – 100 to 1000 pieces per hr. Maximum size of parts is about 35 lb. for zinc and 15 to 18 lb. for light metals. Die casting permits high production and tolerances between ±0.001 to 0.003 in.

Precision investment casting has been one of the significant wartime production developments in metalworking. Patterns are composed of waxes or plastics that can be melted, vaporized or burned without leaving a residue. (One variety uses frozen mercury for patterns.) Patterns are prepared by injecting the wax or plastic into metal dies. These dies in turn are made most simply by casting two halves around master patterns made of metal; maximum precision may require engraved and hand-finished dies in steel. The wax, plastic or mercury pattern is placed in a flask, and the mold investment (usually ceramic or plaster) is poured around it. When the plaster has hardened the wax is melted out. This leaves a molded cavity into which molten metal is poured to form the casting, usually under moderate pneumatic pressure.

This method is used for making precision parts of hard alloys that are difficult or virtually impossible to machine. Brass, bronze, stainless steel, but especially temperature resisting alloys such as stellite, Vitallium, and Nimonic, are worked with this method. Die costs are fairly low because the master mold never wears out. Direct labor costs, on the other hand, are very high. Finishing costs are low, since machining is often eliminated entirely. It takes sometimes only a few hours (using a sample part as master mold) to get into production with precision investment casting. The output is slow – hardly more than 40 to 60 pieces per hr. Fairly large

Table I – Economic Characteristics of Seven Methods of Manufacturing Small Parts

Factor	Permament Mold Castings	Die Castings	Investment Castings	Screw Machine
Cost of metal	Low	Medium	High	Low
Die or tool costs	Moderate	High	Moderate	Moderate
Direct labor	Low	Medium	Very high	Very low
Preparatory time	1 to 3 weeks	2 to 5 weeks	6 hr. to 6 days	7 days
Production per hr.	50 to 80	100 to 1000	40 to 60	Up to 3000
Max. weight or size	50 lb. (aluminum)	35 lb. (zinc) 18 lb. (aluminum)	2 lb.	2½ in. dia.
Precision	0.0015 to 0.010	0.001 to 0.003	0.002 to 0.005	0.001 to 0.003
Final finishing	Minimum	Low	Low	Very low

parts can be made with this method, although experience shows that parts under 2 lb. can also be readily manufactured. Extremely high precision is obtained, with tolerances of the order of ± 0.002 to 0.005 in.

Screw machine parts are not necessarily screws or even threaded parts, but include all types of small machined parts produced rapidly and repetitively from bar stock or tubing and involving lathe-machined surfaces that are turned, formed, drilled, threaded or cut off. The materials used are free-machining steels, free-cutting brass, aluminum and magnesium alloys, and other metals. These raw materials are not expensive. Costs for the common tools range between $150 and $250. Since the operations are usually automatic, direct labor costs are very low; one man can watch several machines. Finishing costs are low; all that is required is some cleaning. Output is very high – up to about 3000 parts per hour. This method is usually used for very small parts, although parts up to 2½ in. in diameter and two or three times as long have also been made. Customary tolerances range between ± 0.001 and 0.003 in., sometimes even higher.

Stamping may be defined as forming or pressing metal parts out of sheet using presses or drop hammers. The material is formed in or over a die with a movable punch which may be a rigid form or a thick pad of rubber. Raw material costs are very low, while die and tool costs are usually high – $400 to $1200 for small parts dies, although for short runs on larger items hard wood, cast zinc, or assemblages of steel subdivisions are quite useful. Direct labor costs are medium and depend on the part shape and size. A special finishing operation other than cleaning is generally unnecessary. Design and production of the dies are fairly complicated and slow. Output depends on circumstances, being as low as 25 per hr. in a drop hammer to 2000 or 3000 pieces per hr. in progressive dies, fed automatically. All workable sheet metals can be formed by this method. Size of parts is almost unlimited, from very large parts to those with sections as thin as 0.003 in. Tolerances average around 0.001 in., but may be even closer on very small parts.

Cut extrusion is actually not a special forming operation, but it is a competitor to the powder metallurgy method. Very long extruded pieces of special cross section uniform throughout their length are cut transversely, sometimes after having screw machine operations performed. This method produces parts having essentially the original special cross-section shape but with thicknesses equal to the cut length. Raw material costs are high, but tool costs are extremely low. Skilled labor is not required and labor costs are also very low. Cut extrusions normally only have to be deburred, and finishing costs are therefore very low. On automatic lathes approximately 1000 small parts can be manufactured in 1 hr. Copper, copper alloys, aluminum – in fact, any metal which can be extruded – can usually be worked with this method. Parts 8 to 10 in. in diameter represent the usual maximum size, although the length can be much greater than the diameter. Very small parts (down to a sixteenth of an inch) are possible. Tolerances are in the range of ± 0.005 to 0.020 in.

Powder Metallurgy – Small machine parts are being made by the powder metallurgy method, although its great advantage lies in its use of metal combinations which cannot be produced by any other method. The powders used for raw materials have to satisfy a number of conditions. Among other variables they are stringently checked for contamination, ability to flow, compressibility, particle size and size distribution, and particle shape. For a number of operations powders are usually blended to-

Stampings	Cut Extrusions	Powder Metallurgy	Factor
Very low	High	High	Cost of metal
High	Very low	High	Die or tool costs
High to medium	Very low	High	Direct labor
1 to 4 weeks	1 to 7 days*	2 to 5 weeks	Preparatory time
25 to 3000	1000	Up to 1800†	Production per hr.
Very large to 0.003 in. thick	8 in. dia.	4 sq. in. cross section 18 in. dia.	Max. weight or size
0.001	0.005 to 0.020	0.001 to 0.005‡	Precision
Moderate to very low	Very low	High (if necessary)	Final finishing

*Provided extrusions of correct shape are available.

†For small parts made on single-die "tablet" presses.

‡May be 0.0005 in. for restruck or coined pieces.

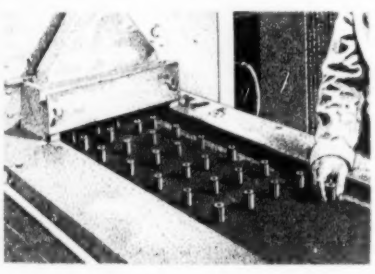
gether to obtain optimum physical and mechanical properties.

The actual powder metallurgy technique goes through the following steps: First the powders are pressed to the desired shape in a die. Fast-working mechanical tablet presses are used for small parts, and slower-working hydraulic presses for larger parts. The form or compact so made is termed the "green" briquette and is normally rather weak. This briquette is then heated at a temperature usually below the melting point of at least one of the metals making up the compact. This operation is called sintering; it strengthens and densifies the compact. Once sintered, the pieces can be re-pressed (coined) to size. Special heat treatments may also develop the intrinsic capabilities of the alloy mixtures—for example, iron plus carbon mixes are heat treated into hardened steel.

Some operations combine green pressing and sintering in a single process termed hot pressing. This technique may be used to strengthen the compact or to give it different properties than are obtained by the usual technique outlined above. Dies for hot pressing at temperatures up to 1100° F. are made of high speed toolsteel or high-temperature alloys. Above 1100° F. graphite or ceramic dies are utilized.

Among the unique features of powder metallurgical parts is that they can be processed from metals normally of too high a melting point to be melted in commercial equipment. Metals falling into this group include tungsten for tungsten wire applications and tungsten-molybdenum alloys. Furthermore, reactive metals like beryllium and titanium, reduced as powders, may be consolidated into small rods or billets by powder metallurgical methods, all operations being conducted in vacuum or under protective atmospheres.

Another advantage is the ability to use metal combinations normally impossible to obtain by other methods. Examples are electrical contact parts of tungsten and copper mixtures, or of copper and graphite mixtures. A third feature is that parts can be produced having properties normally unattainable by other fabrication methods, such as porous metal filters and self-lubricating bearings.



The raw material costs are high. So are die costs high, ranging from more than $150 up to several thousand dollars. To amortize these die costs, large quantities of parts (more than 10,000) have to be produced. However, even small runs may be warranted if the special part cannot be readily manufactured by another method. Labor costs in powder metallurgy vary inversely as the production speed. Semiskilled labor is needed for blending, sintering and coining; only a minor amount of skilled help is required. Special finishing operations are seldom necessary, but if required, are difficult. There is virtually no waste metal in this process and scrap losses are very small. Dies are made of hard-to-machine materials and must be designed very carefully. Output is high; 1800 pieces per hr. for very small parts is not unusual. By using multiple-die tablet presses proportionally more pieces can be made. Usually parts are small – up to 4 sq. in. in section and down to less than a sixteenth of an inch in diameter. However, bearings as large as 18 in. in diameter have also been made by powder metallurgy. Tolerances range between ± 0.001 to 0.005 in. for unsized pieces. Coining gives extremely close tolerances – down to ± 0.0005 in.

Powder metallurgy methods for manufacturing small parts of special metals, unorthodox metal combinations or unique properties have little or no competition from other common fabrication methods such as casting and machining.

President Eisenhower's Atomic Proposals*

I FEEL IMPELLED to speak today in a language that in a sense is new—one which I, who have spent so much of life in the military profession, would have preferred never to use. That is the language of atomic warfare.

Atomic bombs today are more than 25 times as powerful as the weapons with which the atomic age dawned, while hydrogen weapons are in the ranges of millions of tons of TNT equivalent. Today, the United States' stockpile of atomic weapons exceeds by many times the explosive equivalent of the total of all bombs and all shells that came from every plane and every gun in every theater of war through all the years of World War II. A single air group, whether afloat or land-based, can now deliver on an available target a destructive cargo exceeding the power of all the bombs that fell on Britain in all of World War II.

But the dread secret and the fearful engines of atomic might are not ours alone. The secret is possessed by our friends and allies, Great Britain and Canada, whose scientific genius made a tremendous contribution to our original discoveries and the designs of atomic bombs. The secret is also known by the Soviet Union. In recent years the Soviet Union has exploded a series of atomic devices including at least one involving thermo-nuclear reactions.

To pause here would be to confirm the hopeless finality of a belief that two atomic collossi are doomed malevolently to eye each other indefinitely across a trembling world. To stop here would be to accept helplessly the probability of civilization destroyed and the condemnation of mankind to begin all over again the struggle upward from savagery toward decency, justice and right.

Surely no sane member of the human race could discover victory in such desolation.

So my country's purpose is to help us move out of this dark chamber of horrors into the light. It is not enough just to take this weapon out of the hands of the soldiers. It must be put into the hands of those who will know how to strip its military casing and adapt it to the arts of peace.

The United States knows that if the fearful trend of atomic military buildup can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind. The United States knows that peaceful power from atomic energy is no dream of the future. That capability, already proved, is here—now—today.

I therefore make the following proposal:

The governments principally involved, to the extent permitted by elementary prudence, begin now and continue to make joint contributions from their stockpiles of normal uranium and fissionable materials to an international atomic energy agency. We would expect that such an agency would be set up under the aegis of the United Nations.

The ratios of contributions, the procedures and other details would properly be within the scope of private conversations among such other countries as may be principally involved. The United States is prepared to undertake these explorations in good faith. Any partner of the United States acting in the same good faith will find the United States a not unreasonable or ungenerous associate.

Undoubtedly initial and early contributions to this plan would be small in quantity. However, the proposal has the great virtue that it can be undertaken without irritations and mutual suspicions incident to any attempt to set up an acceptable system of world-wide inspection and control.

The atomic energy agency could be made responsible for the impounding, storage and protection of the contributed fissionable and other materials. The ingenuity of our scientists will provide special safe conditions under which such a bank of fissionable material could be made essentially immune to surprise seizure.

The more important responsibility of this atomic energy agency would be to devise methods whereby this fissionable material would be allocated to serve the peaceful pursuits of mankind. Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine and other peaceful activities. A special purpose would be to provide abundant electrical energy in the power-starved areas of the world. Thus the contributing powers would be dedicating some of their strength to serve the needs rather than the fears of the world.

The United States would be more than willing—it would be proud to take up with others "principally involved" the development of plans whereby such peaceful use of atomic energy would be expedited. Of those "principally involved" the Soviet Union must, of course, be one.

I would be prepared to submit to the United States Congress, and with every expectation of approval, any such plan that would:

First—Encourage world-wide investigation into the most effective peacetime uses of fissionable material.

Second—Begin to diminish the destructive power of the world's atomic stockpiles.

Third—Allow all peoples of all nations to see that, in this enlightened age, the great powers of the earth, both of the East and of the West, are interested in human aspirations rather than in building up the armaments of war.

Fourth—Open up a new channel for peaceful discussion and initiate at least a new approach to the many difficult problems that must be solved in both private and public conferences if the world is to shake off the inertia imposed by fear and make positive progress toward peace.

Against the dark background of the atomic bomb, the United States does not wish merely to present strength, but also the desire and hope for peace. The United States pledges before you—and therefore before the world—its determination to help solve the fearful atomic dilemma—to devote its entire heart and mind to find the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life.

*Verbatim excerpts from address before General Assembly of the United Nations on Dec. 8, 1953.

EDITOR'S FOOTNOTE—Some two weeks later, the Soviet government issued 3000 words of self praise and foreign vituperation, within which was this sentence: "As to President Eisenhower's statement on the confidential diplomatic talks concerning his proposal, the Soviet Government expresses its readiness to take part in such negotiations."

James Bliss Austin

President of
American Society for Metals
Director of Research,
U. S. Steel Corp.

A Biographical Appreciation

ONCE UPON a happy time (1927), James Bliss Austin and a chemistry instructor from a girls' college, Janet Evans, were studying at Yale for their doctorates in chemistry. The historic Yale Green was still a romantic lawn, the whiffenpoof song the bleat of companionship, the elms of New Haven the fingers of promise. Instilled in all students was the spirit of Josiah Willard Gibbs, founder of chemical energetics, the while throughout this booming land resounded the clamors of industrialized opportunity.

The head of Yale's department of chemistry, the late John Johnston, heeding the call of war-enlightened industry, was quitting the gardens of New Haven for the salt marshes of New Jersey, at Kearny, where U.S. Steel provided him with research facilities. His task was to investigate the fundamentals of steel and their engineering. The staff he soon collected for that U.S. Steel Research Laboratory was an unusually learned and able group. Edgar Collins Bain was to discover eponymic bainite, become ⊖ lecturer, medalist and president, and now his corporation's vice-president for research and technology. Others of that early Kearny group still with U.S. Steel include Edmund Sharington Davenport, an ⊖ Campbell Memorial Lecturer; ⊖ Research Medalist Rufus Eicher Zimmerman; ⊖'s 1953-54 president James Bliss Austin.

Dr. Austin went to Kearny in 1928, as soon as he received his Ph.D. He had been born just outside the District of Columbia on July 16, 1904, of studious English and German ancestors; had gone to Lehigh for his degree in chemical engineering.

Janet Evans was the daughter of a student of Edward De Mille Campbell, great University of Michigan chemical engineer whose memory ⊖ members revere. She had studied and briefly taught chemistry at Mount Holyoke College. With her Yale doctorate she returned there until, in 1930, she and Jim Austin were married.

The Austins live in a pleasant home at Westfield, N.J., where the gentle Watchung Mountains shelve off toward the low coastal plain that takes in Kearny. Their two children, Peter, age 15, and Winifred, 12, play the piano with their mother and enjoy their father's singing with the neighborhood choruses. They all like to ride, have spent one summer in Colorado on a friend's working ranch, and hope that they can get out there again to see a far horizon. At home in Westfield they have a homelier ambition — to raise a drapery of flowers on a stubborn rock wall near their house.

For a while after their marriage Mrs. Austin did private research, plus a stint with Merck & Co., the pharmaceutical manufacturer. Both she and her husband have been contributing since 1930 to *Chemical Abstracts*. Theirs is the kind of harmonious household that sustains a man's enthusiasm for his work.

All James Bliss Austin's career has been with the U.S. Steel Research Laboratory at Kearny — physical chemist, 1928-41; supervisor of chemistry, 1941-44; assistant director, 1944-46; director since 1946, when Dr. Johnston retired.

As director, his charter is to carry out the long-range basic work of wide interest to all of U.S. Steel. This will not be affected, at least for the next few years, by the new research center which U.S. Steel is just starting to build in Pittsburgh. That center has problems closer to production than does Kearny.

The Kearny staff normally numbers 50 professional men, with some 35 assistants. These include a librarian with her complete, though small, professional library and its proper complement of periodical literature. The staff maintains temperature standards for use in calibrating optical pyrometers throughout the Corporation's activities. By special high-speed photography they are making new observations of what goes on within furnaces. In all, they are among the most active of scientists who are developing a prescription metallurgy.

Dr. Austin's personal researches have been broadly in chemical thermodynamics, thermal expansion measurements on metals and refractories, adsorption of gases on plane surfaces of metals, flow of heat in refractories and metals. He delivered the 1941 series of five educational lectures which ⊖ published as "The Flow of Heat in Metals". His Campbell Memorial Lecture (1946) was on "The Effect of Changes in Condition of Carbide on Some Properties of Steel". In 1952 he gave the American Ceramic Society's Orton Lecture on "Thermal Expansion of Nonmetallic Crystals". He has also published some 50 other papers. A research executive now, he is chiefly concerned in seeing that whole programs mature rather than doing specific research himself.

Corollary to his executive position is his duty to represent U.S. Steel before professional societies, business groups, educational assemblies, communal organizations. He has already spoken before many ⊖ chapters, will spend much of his presidential year with the members. In November last he represented both ⊖ and

U.S. Steel on a quick trip to England. As president of ASM he participated in a meeting in London of the top executives of various British and European technical societies to further plans for the Second World Metallurgical Congress in 1955. As representative of ASM and also of U.S. Steel, he attended the dedication of the British Iron and Steel Research Association's new laboratory in Sheffield. During the ceremonies he was honored by being the only American included in a group of prominent Britishers formally presented to the Duke of Edinburgh.

Besides ASM and the Ceramic Society, he belongs to the American Electrochemical, Optical and Chemical societies, to A.I.M.E., the American and British Iron & Steel Institutes, the British Ceramic Society and Franklin Institute.

In the American Society for Metals, leading up to the 1953-54 presidency, he has been 1952-53 vice-president, 1950-52 trustee, 1944 chairman of the New York Chapter. He maintains a close interest in the services that the several publications give to the members and to industrial executives. He wants metallurgists to know and value their profession's history.

In person Dr. Austin is a soft-speaking, candid, learned and aphoristic scholar. Says he: "As the amount of our knowledge increases, the statement of that knowledge can be made more brief." Other Austinisms: "It is always good scientific policy periodically to question any assumption that has come to be taken for granted." . . . "Appropriation of the work of a single investigator is considered as plagiarism; taking data from 20 is condoned as research." . . . "It is always dangerous to draw inferences as to what is in a solution from observations of what separates out under given conditions."

Dr. Austin smokes a pipe. Now, "under a given set of conditions", this might "prove" that he is a metallurgist, for the ball-bowled briar seems to have become the symbol of the profession — whether as adoration to the alembic or as deference to the bessemer, or for some still more recondite reason. There indeed does seem to be a recondite factor in James Bliss Austin, for he is a member of the sleuthy Baker Street Irregulars. In their spoofing quarterly, *The Baker Street Journal*, he has published various papers, one of which "proves" that Dr. Watson was twins. Like Sherlock Holmes, deductive preceptor, Jim Austin does find that the whiff-and-puff of a hand-cuddled cucurbit is really conducive to ratiocination. MYRON WEISS

Light Metallurgy

The Rise and Fall of the Raines Law Sandwich

FOR A NUMBER of years the good citizens of Pennsylvania were harassed by an overbearing set of Blue Laws. There could be no Sunday baseball, no beer, no ice cream sold except with meals, and in some parts of the state one hardly dared drink pop on Sunday except up an alley.

In State College, Pa., in the early twenties, there lived a Greek candy store proprietor named Hunkadoklios close to the campus of Pennsylvania State College. Students never had money enough to buy both ice cream and sandwiches at the same time, and with the perversity of human nature, always wanted ice cream on Sunday and sandwiches on week days. As a result, Hunkadoklios had to pay a fine each week for the privilege of serving them ice cream on the Sabbath.

Tiring of this bother and expense, he conceived the idea of placing a "prop", or dummy sandwich on each table at no charge. There were some disadvantages to this idea, however, on two counts:

1. From the aesthetic standpoint the sandwiches suffered much. They collected dust, flies and mold; after a few weeks' exposure to atmosphere and students they took on a most unappetizing pepper-and-salt tweedy surface with green overtones.

2. The students sometimes played table baseball with them, causing a certain deterioration, even after a coating of white shellac was added by the inventive Greek.

Hunkadoklios then had his prop sandwiches made of wood, suitably painted and fastened with light chains to the edges of the tables. This did not work out well either, for several reasons, principal among them being:

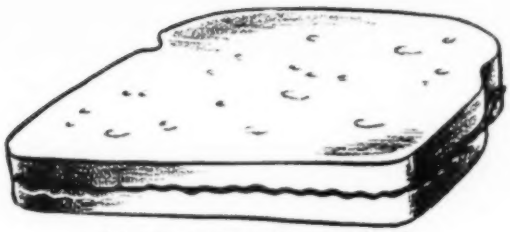


Fig. 1 – Raines Law Sandwich in Original Weather-Beaten Rye

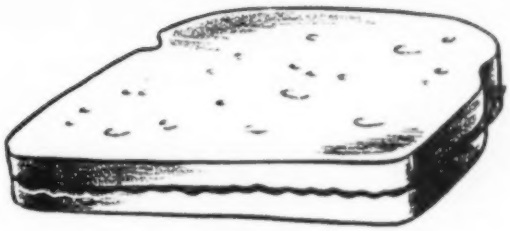


Fig. 2 – Raines Law Sandwich Executed in Soft Pine

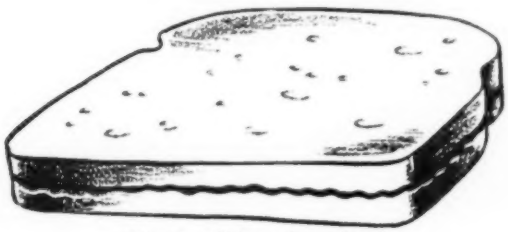


Fig. 3 – Raines Law Sandwich as a Gray Iron Casting

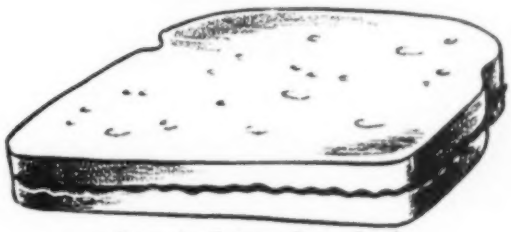


Fig. 4 – Raines Law Sandwich Redesigned for Malleable

Adventures in Functional Redesign

1. People used them for ashtrays, which left them somewhat charred and spotted.

2. The cook used them to start fires when kindling wood was scarce.

One day the proprietor found a copy of a foundry tradepaper left behind by an absent-minded Penn State student. That gave the Greek an idea. Hunkadoklios wrote a lengthy letter to a foundry in a suburb north of Philadelphia, and soon there arrived a set of prop cast iron sandwiches, with realistically textured surfaces.*

Papa Hunkadoklios even went so far as to order both white and rye, painted with white and brownish gray enamel respectively. Ham was suggested by a thin dark line in the middle of the crust edges, with a thin wavy line of green to indicate lettuce. (Unfortunately this delicate coloring did not hold up too well.)

These cast iron "Raines Law" sandwiches immediately caught on among the ice cream parlor proprietors of Pennsylvania, and the foundry did a thriving business for years. They sold unusually well in Mauch Chunk, Pottstown, Punxsutawney, Tidioute, and in the southern part of Norristown. In the rush of business some of the sandwiches were turned out with blowholes the size of worm tunnels, and these were classed as Genuine Antiques, fetching high prices from the antique hunters of New York and Philadelphia.

But one day a catastrophe struck the cast iron sandwich industry. On a Sunday in fall, after Bucknell University had beat Penn State by a score of seven to six, a group of "Old Main Rats" who had pooled $17.65 to bet with a gang of "Town Muckers", engaged in a melee with some of the football players in Hunkadoklios's ice cream store. The enraged Old Main Rats threw the cast iron sandwiches at the football players' heads. Since the cast iron was more brittle than the heads (the sandwich carbon being in the form of flake graphite), the sandwiches disintegrated readily. The football players did not disintegrate, but merely dispersed.

Hunkadoklios cried in his coffee.

Then there came along a Tau Bete named Schlackenbaugh, who was majoring in metallurgy and itching to apply his textbook knowledge in some practical engineering fashion. Schlackenbaugh suggested two alternatives – the sandwiches could be redesigned to be cast either from electric molybdenum alloy steel or from malleable iron. (The metallurgist did not suggest nodular iron, principally because such had not been heard of at that time.)

Schlackenbaugh suggested malleable as being the least expensive, so Hunkadoklios sent the sandwich pattern to a foundry somewhere around Albion, Mich. In due time he received

*The method of making the pattern is interesting. A real ham sandwich was dusted with powdered graphite, then put into an electroplating bath and a coating of copper of suitable thickness was deposited thereon. This made a pattern sufficiently strong to withstand the effect of ramming the sand in the mold. The sandwich casting came out somewhat caved in at the flat surfaces, which made for even greater realism, since ice cream parlor sandwiches are known to be somewhat subject to surface dehydration.

a large package containing half a hundred sandwiches for trial, individually wrapped in white tissue paper and tied with red ribbon. This new product was such a masterpiece of verisimilitude that samples, wrapped and unwrapped, were displayed at the local Co-op Bookstore.

Unfortunately for the budding malleable sandwich industry, just at this time the blokes in the State Legislature at Harrisburg up and killed the Blue Laws. WALDIMIR ANDERSON

Book Review

"New" Materials for High Temperature

BY ROGER A. LONG*

REFRACTORY HARD METALS, by Paul Schwarzkopf and Richard Kieffer. 447 p., 91 illustrations. Macmillan Co., New York City. $10.

WHAT ARE THE "refractory hard metals"? The subtitle of this book tells us that they are "borides, carbides, nitrides, silicides", and the authors in their introduction state that "the term 'hard metals' is used to specify a group of high-melting hard substances which have metallic character although, on the basis of chemical composition, they would be considered inorganic compounds." Typical representatives are the refractory carbides of the transition metals, particularly tungsten, titanium and tantalum.

This book is primarily a review of the literature covering approximately the past 80 years, with background comments by the authors, Paul Schwarzkopf, president of American Electro Metal Corp., and Richard Kieffer, director of Schwarzkopf's Austrian plant, Metallwerk Plansee, Reutte, Tyrol. It brings to the reader a new group of materials which opens wide a new field of metallurgical intrigue.

It is important to mention here that many of these compounds have been well known in literature but no research was done to develop their properties because no particular need had been seen. The bibliography is extensive and the authors and their associates should be congratulated on searching out this information and interpreting and condensing it. There is no question that this book will become a bible to those concerned with refractory metals.

Most of the early work on hard metals was done in Germany and in France. The advent of powder metallurgical techniques and the application of these techniques to tungsten carbide cutting tools opened wide the field of technological advancement in the 1920's. The authors first lead the reader into the realm of scientific metal physics to give him a basic understanding of how these compounds are formed and their metallic bonding characteristics. The early chapters of the book deal with the carbides, since they may be regarded as the parents of these new compounds and have already had considerable development. Even in the carbide system, the various researchers do not agree as to the structure of the product or as to the mechanism involved. The authors discuss the borides, nitrides and silicides – all new "materials" in the past decade, even though they were known in the preceding century. The data and conclusions of the researchers are given fluently, and the authors do not question or decide between that which is good and that which is bad. This is excellent, for the authors do not set themselves up as critics, but present the literature in an orderly fashion as it was published.

In checking a number of the literature references, this reviewer has found that many are excellent and accurate condensations. He has occasionally found that the authors have slightly misinterpreted some of the literature. This is important because if the information from this book is to be used extensively for research, it might be desirable for the investigator to go back to the original reference rather than base his work upon the authors' interpretation.

In the preface and also toward the end of the book, the authors indicate that the primary reason for the book is to facilitate use of these materials in high-temperature applications. Because so much of the information on high-temperature properties of these new materials is restricted, these chapters fall far short of expectations. In the next edition, this reviewer would like to see references to the restricted literature – or, better yet, the release of a lot of restrictions!

The authors are indeed to be praised for this work, and such a deal of information available in one place will advance developments in this field by a number of years.

*Mr. Long is manager, Aircraft Components Div., Ferrotherm Corp., Cleveland.

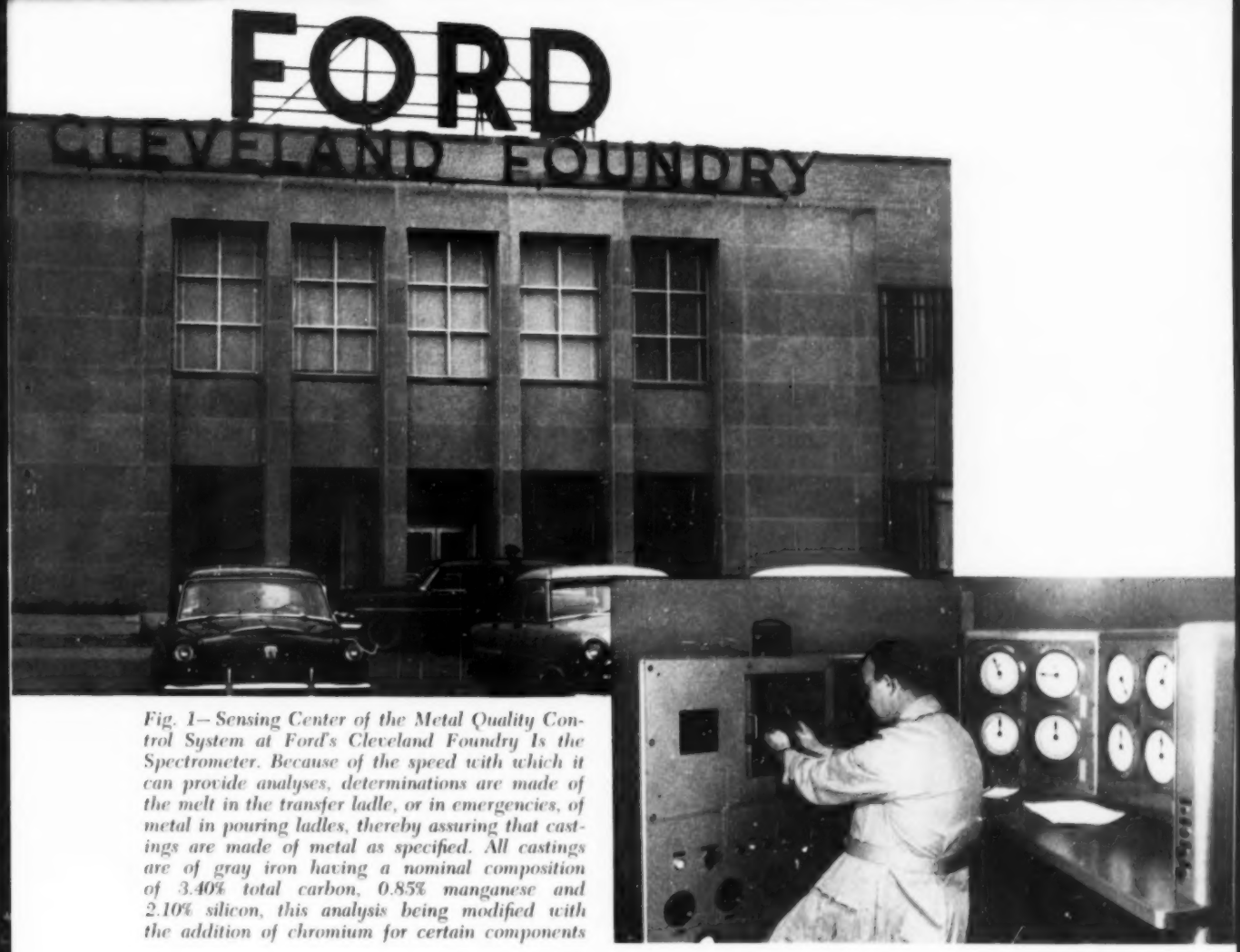


Fig. 1— Sensing Center of the Metal Quality Control System at Ford's Cleveland Foundry Is the Spectrometer. Because of the speed with which it can provide analyses, determinations are made of the melt in the transfer ladle, or in emergencies, of metal in pouring ladles, thereby assuring that castings are made of metal as specified. All castings are of gray iron having a nominal composition of 3.40% total carbon, 0.85% manganese and 2.10% silicon, this analysis being modified with the addition of chromium for certain components

Controlling Metal Quality at Ford's Cleveland Foundry

FAST, accurate control of metal composition is a critical factor in the efficient operation of the Cleveland Foundry of the Ford Motor Co. which pours 2000 tons of gray iron from 5 of its 10 cupolas in a 16-hr. day. A few of the many points of interest in this foundry, which started operations two years ago, are the following: All of the cupolas are of the hot blast type having continuous front slagging and equipped with forehearth to receive a continuous tap. Floor area is over a million square feet, with inside storage for 54,000 tons of sand. There are eight molding lines, 66 molding machines, and each line is supplied by three 50-ton per hr. sand mullers. Seacoal and bentonite are pumped in slurry form from a central station direct to molding line mixers. Air in the foundry is changed completely every 10 to 12 min., with 2,800,000 cu. ft. of air being taken in every minute.

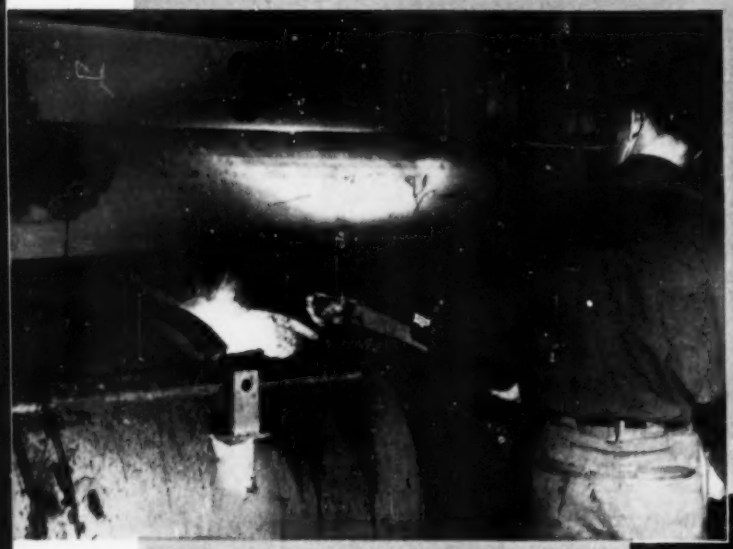


Fig. 2 — Sample of Melt Being Taken From 2-Ton Transfer Ladle for the Casting of Pin and Chill Specimens

Fig. 3 — Pin Samples, Measuring 7/32x1¼ In., Provide Means for Checking Basic Chemistry of Melt. If necessary, chemical composition is adjusted in the pouring ladles and line samples (cast as pins) are used to check the analysis following such additions. Molds in foreground are for pin samples. Test pieces in rack in the background are chill samples which have been fractured to examine the structure for machinability of the metal. Here again additions, if necessary, can be made at the line to improve this property

Fig. 4 — Pins Are Sent by Pneumatic "Transit-tube" to Chemical Laboratory for Analysis. Chart shows silicon content of melt for intervals of ½ hr.; points outside upper and lower control limits will indicate need for correction. A similar chart is used to show control of carbon

Fig. 5 – Melt, in 1-Ton Pouring Ladle, Being Corrected With the Addition of Chromium for Castings of Cylinder Heads (0.20 to 0.25% Cr) and Flywheels (0.20 to 0.40% Cr)

Fig. 6 – Of the 35 Different Items Cast for Ford and Mercury Cars, Largest Components Are Mercury and Ford 6-Cylinder Motor Blocks. Above, Ford blocks are being transferred to cooling conveyer at the shakeout

Fig. 7 – Approximately 165 Samples Are Run in an 8-Hr. Day. Total time for simultaneous analysis of six elements takes less than 40 sec.; this includes a light chamfer grind on ends of pins, 7-sec. pre-spark and 10-sec. exposure. Analysis is for the major elements of Mn, Si and Cr, plus the residual elements Mo, Cu and Ni

Fig. 8 – Carbon, Sulphur and Phosphorus are Determined by Conventional Combustion Methods, None of Which Takes More Than 3 Min. Hardness measurements are made on a representative sample of castings, as well as on bars used for tensile strength tests which are made periodically

By NORBERT K. KOEBEL*
Director of Research
Lindberg Engineering Co., Chicago

Dew Point — a Means of Measuring the Carbon Potential of Prepared Atmospheres

THE ENDOTHERMIC (heat absorbing) type of atmosphere generator has been accepted by industry as the most convenient and practical for preparing furnace atmospheres for the heat treatment of medium, high-carbon and toolsteels. The primary reason is that natural gas, now available throughout the country, can easily be cracked to produce a consistent atmosphere to meet the requirements of neutral hardening, carbon correction, and homogeneous carburizing without elaborate gas generating equipment requiring chemical purification and drying towers. The endothermic generator can be operated by any shop man and the only instrument required to adjust the generator so it is in equilibrium with a steel of any given carbon content is a simple dew point meter, or an instrument for measuring moisture in the gas it produces. This statement is made with confidence, since the research laboratory of the Lindberg Engineering Co. has completed a five-year study of the equilibrium relationships between the dew point of endothermic furnace atmosphere and straight carbon steels, low-alloy production steels, and toolsteels. The purpose of this article is to publish the results of this study so that heat treaters can get the desired results with precision.

As is shown in Fig. 1, hydrocarbon gas and air are metered in such a proportion that there is just sufficient oxygen to form carbon monoxide and hydrogen without any excess for carbon dioxide or water vapor. After the air-gas mixture is compressed to about 1 or 2 lb. gage, the mixture is passed through a firecheck and then to the heated catalyst in a pressure-tight retort heated externally (usually by gas firing). The temperature of the catalyst is extremely important to obtain a gas completely reacted and of consistent analysis. A temperature from 2000 to 2200° F. in the heating chamber outside the retort obtains a completely reacted and stable gas mixture.

THE ENDOTHERMIC REACTION

After the gas passes over the catalyst, the reaction is "frozen" by chilling the gases to 600° F. in a water jacket surrounding the top of the retort, thus preventing the reaction from reversing and forming carbon and carbon dioxide from the carbon monoxide. (The reaction in that direction occurs in a temperature range from 1300 downward to 900° F.) The soot-free, reacted gas can be further cooled in the gas cooler for metering and distribution purposes if desired.

*The author would like to express his gratitude to Charles A. Mueller and to Gerald L. Scott of the Lindberg Engineering Co.'s research laboratory, who conducted hundreds of tests and gas analyses to establish the equilibrium curves presented in this paper.

Considering natural gas to be composed chiefly of methane (CH_4) the over-all chemical reaction taking place in the endothermic generator may be written:

$$2\ CH_4 + O_2 + 3.8\ N_2 \rightarrow 2\ CO + 4\ H_2 + 3.8\ N_2$$

This over-all reaction is not endothermic as the generator name implies, but actually exothermic—it liberates 8500 cal. of heat per mol equivalent. However, the reaction takes place in two stages. In the first stage, some of the methane burns with the air and of course generates heat. In the second stage, the surplus methane reacts with the carbon dioxide and water vapor produced in the first stage, and this second reaction is definitely endothermic. Therefore, a high temperature and sufficient catalyst bed are required to obtain complete reaction so there is no carbon dioxide, excess methane, or excess water vapor in the final effluent. A reversible reaction is then prevented by "freezing" the reaction, as explained above.

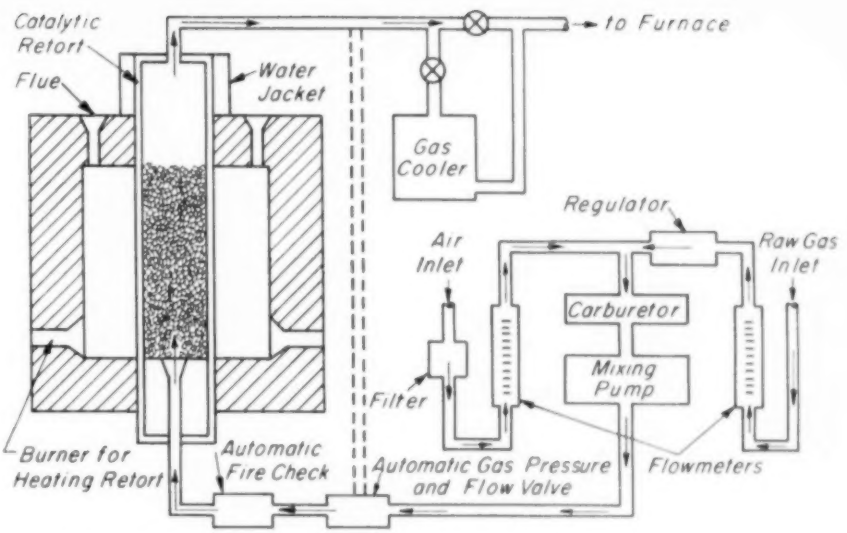


Fig. 1 – Schematic Flow Diagram of Endothermic Atmosphere Generator, Producing a Relatively Dry Mixture of CO, H_2, and N_2 From Natural Gas and Air

Figure 2 shows that the air-gas ratio can be altered slightly to vary the dew point (moisture content) of the gas without appreciably affecting the carbon dioxide or residual methane. Note that from a 35° F. dew point down to 0° F. dew point there is no carbon dioxide in the atmosphere. The residual methane ranges from none to approximately 1.5% at zero dew point. The methane should never exceed 1.5% if the generator is operating efficiently. If the dew point is above 35° F., no methane will be present but carbon dioxide will steadily increase as more air is used in the air-gas ratio until at a 70° F. dew point, there will be about 1% CO_2. Experience has proven that dew points from 70 to 10° F. will be in equilibrium with steels containing from 0.20 to 2.0% carbon content.

In using endothermic atmospheres for heat treatment, particularly at the austenitizing temperature for hardening, the following rules of thumb were worked out by experience:

For high-carbon and toolsteels, except high speed, use a dew point temperature *in the furnace* from 20 to 40° F.

For high speed toolsteel, it should be between 10 and 20° F.

For medium-carbon and low-alloy structural steels, use dew point temperature of 45 to 60° F. in the furnace.

For stainless steels, use 60 to 70° F.

For gas carburizing, use dew point of 20° F. and enrich with approximately 10% natural gas.

For carbo-nitriding, use dew point of 40° F. max. in furnace and enrich with 5% natural gas and 20 to 30% anhydrous ammonia gas.

EQUILIBRIUM CURVES

The above rules of thumb have generally worked very well for hardening operations, but today there is a definite need for more precise equilibrium atmosphere data for such operations as carbon correction, homogeneous carburizing and for high-temperature operations such as copper brazing without decarburization.

Data for the equilibrium curves were obtained

Table I–A Typical Set of Atmosphere Analyses

Constituents	From Generator	In Furnace			
		1400° F.	1600° F.	1800° F.	2000° F.
CO_2	0.0	0.0	0.0	0.0	0.0
O_2	0.0	0.0	0.0	0.0	0.0
CO	20.2	20.2	20.4	20.4	20.6
H_2	41.4	41.9	41.2	42.3	42.4
CH_4	0.2	0.2	0.2	0.3	0.2
Dew point	20° F.	25° F.	23° F.	16° F.	13° F.

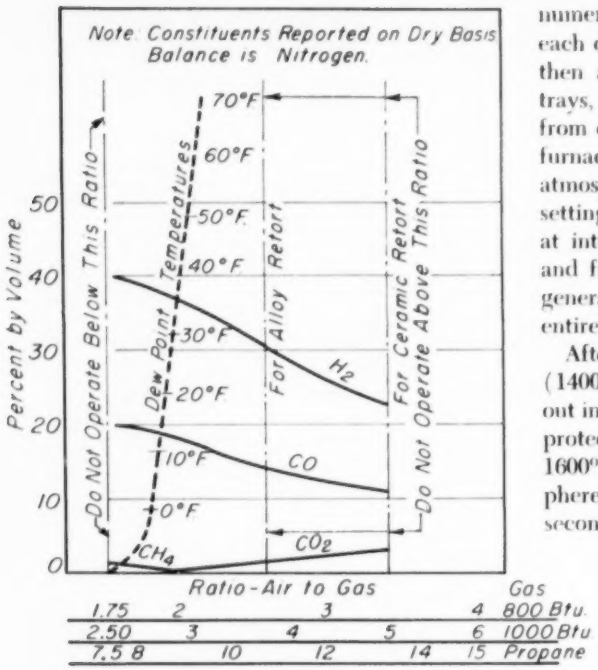


Fig. 2 – Approximate Analysis of Endothermic Generator Gas When Cracking Various Gas-Air Mixtures, the Gases Being Either Natural Gas of 800 Btu. per Cu. Ft., 1000 Btu., or Commercial Propane

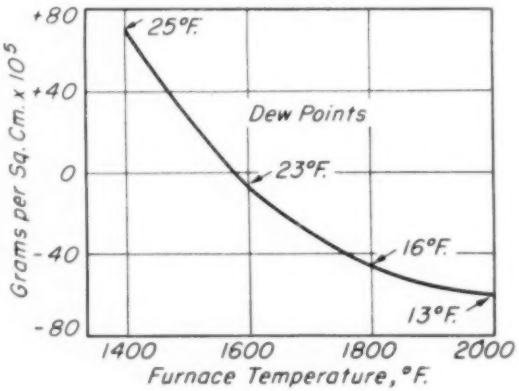
by a laborious method of exposing hundreds of samples of the plain carbon steels, low-alloy production steels, and toolsteels, to a range of dew points from zero to 70° F. at heat treating temperatures from 1400 to 2100° F. (up to 2400° F. for high speed). The change-in-weight method, described in detail by the present author on p. 142 of the book on "Controlled Atmospheres", was used. Samples were prepared by turning down 1-in. bars to ⅞ in. diameter, and cutting into ¼-in. disks. The samples were heated in a standard Lindberg "L" type toolroom furnace. This furnace was selected because, first, it is an industrial furnace and not a small laboratory furnace which might give different results; second, it contains two heating chambers that provide the necessary range from 1400 to 2400° F.; third, it has a cooling chamber necessary to cool the samples in protective atmosphere without scale, for accurate change-in-weight measurement.

Suppose we were working on straight carbon steels of A.I.S.I. series C 1000. We would secure commercial bars of various carbon contents ranging from 0.30 to 1.20%, and analyze the bars for carbon. We would then prepare numerous disks from each bar, properly mark each one, measure it and weigh it. We would then assemble five groups in as many wire trays, each tray containing duplicate samples from each bar. One tray would be put into a furnace at 1400° F. containing prepared atmosphere produced by a given generator setting. Atmosphere was sampled and analyzed at intervals from both the generator exhaust and from the furnace near the samples. The generator setting was not changed during the entire run.

After the samples had been at temperature (1400° F.) for one hour, this tray was pushed out into the cooling chamber and cooled under protective gas. The furnace was raised to 1600° F., and allowed to stabilize for atmosphere and temperature conditions, and the second tray was inserted. (Meanwhile the first tray had been removed and the samples put under study as described below.) This routine was continued until we had one tray of C 1000 steel samples, originally of various carbon contents, which had been heated in a certain endothermic atmosphere one hour at temperatures of 1400, 1600, 1800, 2000 and 2100° F., respectively.

Gas analyses from a typical run are shown in Table I on the preceding page. Note that as the furnace temperature varies, the dew point in the furnace varies, although moisture in the entering gas and its flow were kept constant. For this reason, it is necessary to take dew points from the furnace near the work to establish correct equilibrium curves. Conversely, when using the curves, dew point must be taken from the furnace. All dew point measurements were made by an indicating Alnor 7000U Dewpointer manufactured by the Illinois Testing Laboratories.

Fig. 3 – Method of Plotting Change-in-Weight Data to Obtain an Equilibrium Point



Heat treated samples were reweighed and the change-in-weight calculated on the basis of grams per square centimeter.

Results for each steel treated at the various temperatures were then plotted as in Fig. 3. The intersection of the curve and the zero line for no change in weight marked the temperature for the equilibrium between that steel sample and the moisture (dew point) of the prepared atmosphere. (The actual dew point would be estimated from the two measurements closest.) The experiments plotted in Fig. 3, for example, show that S.A.E. 1095 is in equilibrium with a "Hyen" endothermic atmosphere of dew point 24° F. at 1590° F. (1600° F. for practical purposes). This established one point for the final set of equilibrium curves for carbon steels, which are plotted as the left-hand set in the data sheet, p. 96-B.

Fig. 4 – Typical Micrograph (at 100 ×) of a Steel After Heating 1 Hr. in Equilibrium With Furnace Atmosphere. 1095 Steel, 1600° F., furnace dew point +23° F., loss in weight 0.0001 g. per sq. cm. Gas analysis: CO_2 nil, CO 20.4%, H_2 41.2, CH_4 0.2, O_2 nil, N_2 balance

Runs were repeated with different dew points until enough points were determined to establish a full set of curves for equilibrium of plain carbon steels (0.30 to 1.10% C) at various temperatures (1500 to 2100° F.). These are shown at the left of the data sheet, p. 96-B. Each of these curves was then checked by re-running more change-in-weight samples at indicated conditions and examining them under the microscope. Figure 4 shows a typical micrograph. On this rechecking, a change in weight of ± 0.00010 g. per sq.cm. was considered within equilibrium. Actually, twice that variation cannot be detected by the microscope or by the hardness tester.

The above method was used to determine the set of equilibrium curves for the alloy production steels, and the results are shown in the right-hand graph in the data sheet, p. 96-B. The straight high-carbon steels are of the electric furnace toolsteel type.

Toolsteels – The table at the foot of the data sheet represents the equilibrium data for the austenitizing temperatures of various toolsteels*. Since the heat treater is primarily interested in the hardening or austenitizing temperature, time was not taken to determine correct conditions for the whole range. Figures for toolsteels in the table at the bottom of the data sheet indicate the equilibrium dew point, as well as the permissible range in moisture that will not cause detectable carburization or decarburization in the normal heat treating time.

Note that there is no equilibrium point noted for 2.0% carbon, 12.5% chromium, oil hardening steel at 1750° F., nor for the 1.5% carbon, 12.5% chromium air hardening type at 1850° F., wherein the high chromium acts as a carbide former. These steels are stable to endothermic atmosphere over a wide range of moisture, from 20 to 70° F. dew points. Change-in-weight tests show both these steels to be slightly carburized, but still within the permissible range of ± 0.00020 g. per sq.cm.

USE OF EQUILIBRIUM CURVES

In applying the equilibrium curves, it is of utmost importance that the dew point be taken *from the furnace chamber* and not from the generator. Table I shows that for the same flow of atmosphere, the dew point will vary depending upon the furnace temperature. Still more important, the dew point from the furnace will immediately show trouble – too small a flow of atmosphere, leaky furnace seals, infiltration of moisture or air from the quench tank. Any air leaking into the furnace or carried into the furnace with the charge of work will cause the dew point to rise. Likewise, opening and closing the door will raise the dew point even though the door is protected by flame

*Since there is no accepted standard classification of toolsteels, the author has described each steel as briefly as possible in the table and then given a typical tradename to enable the heat treater to identify the class if he is in doubt. Such use of tradenames is not meant as an endorsement of any particular brand.

Practical Uses for Equilibrium Curves

curtains. Sufficient flow of atmosphere must be put through the furnace to return the dew point to the desired level before the work reaches temperature.

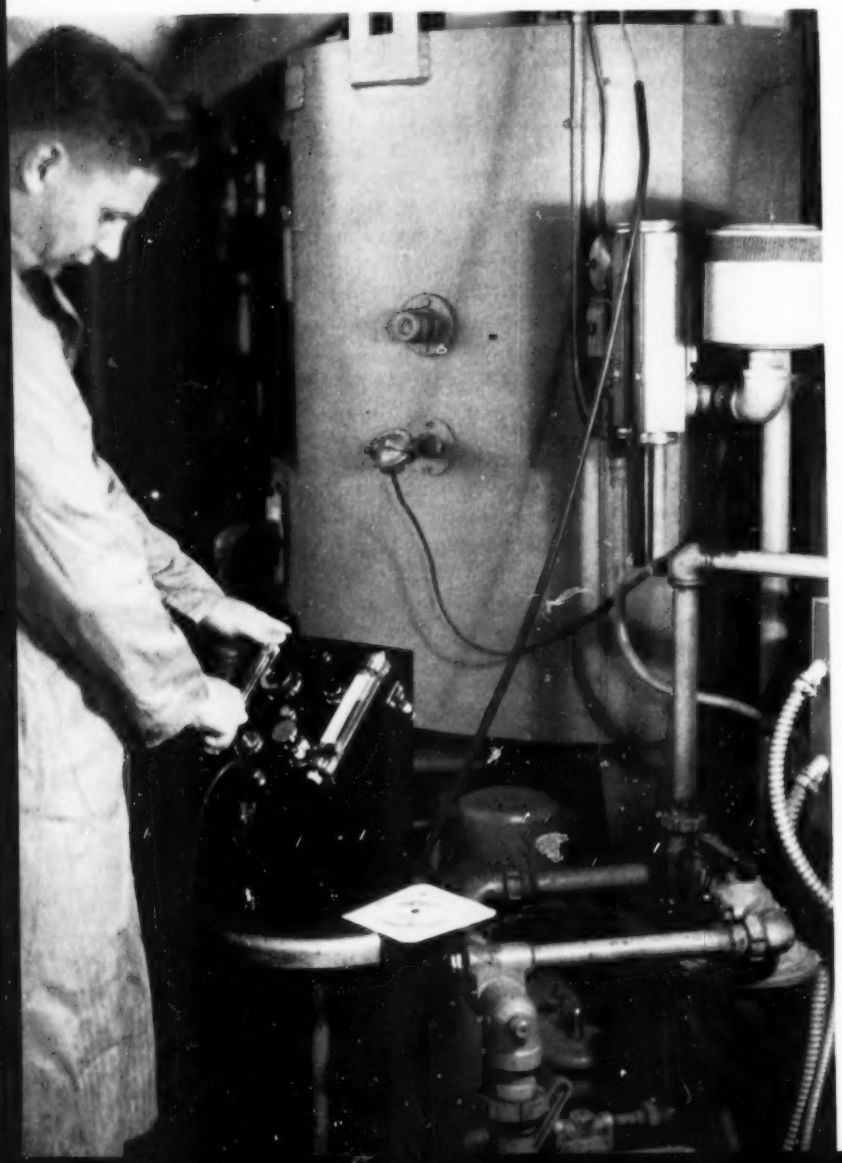
The application of the equilibrium curves in the data sheet, p. 96-B, for neutral hardening is quite obvious. All that is required is to adjust the endothermic generator and flow of atmosphere through the furnace so the indicated dew point temperature is maintained in the furnace chamber at the hardening temperature for the steel being treated.

The table for toolsteels in the data sheet shows that it is not necessary to adjust the dew point closer than ± 5° F.; this will usually give perfect results as checked by the hardness tester. A general rule to follow is that the higher the temperature or the longer the soak, the closer the dew point should be to the equilibrium conditions.

Carbon Correction – Equilibrium curves are particularly useful in the carbon correction of steel. Aircraft specifications for such things as bolts require that any "mill bark" on the surface be recarburized to the content of the core. Bolts with rolled threads are one example where decarburization is not removed in manufacture, and inasmuch as low carbon on the surface of the thread lowers its fatigue properties, specifications for highly stressed bolts now call for carbon correction. To this end, all that is required is to allow the bolts to soak long enough at the hardening temperature with the dew point adjusted in the furnace as shown on the equilibrium curve for the steel being treated.

For example, if an S.A.E. 4140 steel were being heat treated and simultaneously carbon corrected, a hardening temperature of 1600° F. would be used, and the right figure in the data sheet (p. 96-B) shows that a furnace dew point of 55° F. would be in equilibrium with this steel. If the bolts were soaked long enough at 1600° F., the carbon would be restored to 0.40% and there would be no danger of exceeding this amount regardless of time at temperature. (Usually a soak about twice that required for normal hardening is required.)

Fig. 5—Operator Taking Dew Point at Lindberg Hyen Endothermic Generator With Alnor Dewpointer



Some manufacturers use a slightly lower dew point than equilibrium to reduce the soaking time and to counteract surface conditions that may adversely affect equilibrium. Care should then be taken to soak long enough for complete carbon correction to the core and to avoid too high a carbon "potential" (really, a lower dew point) which will carburize the surface.

Equilibrium curves are also very useful for "homogeneous carburizing", which may be defined as carburizing a low-carbon steel throughout to a uniformly higher carbon. This process is used to advantage to carburize low-carbon steel stampings (up to 1/16 in. thick) rather than working a 0.70% carbon annealed sheet. More complicated stampings with sharp bends can be formed with-

out cracking, and furthermore the low-carbon steel is considerably cheaper. The heat treating cycle is considerably longer but, on thin stampings, the process is still more economical than using the higher-carbon steel.

For example, homogeneous carburizing to a 0.70% carbon content for spring properties should be done under equilibrium conditions for 0.70% carbon. The left-hand diagram of the data sheet shows that this can be done at 1600° F. with a furnace dew point of 35° F., or at 1550° F. with a furnace dew point of 42° F., or at a number of other possible combinations. If the stamping is 0.020 in. thick, about 45 to 60 min. at heat will be sufficient at 1600° F. The stampings are quenched directly from the furnace and are ready for tempering to the desired spring properties.

Deep Case — The equilibrium curves are also useful for deep case carburizing where specifications call for a definite carbon content. The advantages of using endothermic generator gas as a carrier gas in gas carburizing have been recognized by industry and this has become a standard method. The standard procedure is to use an endothermic gas of low dew point (10 to 20° F.) and to enrich this atmosphere with about 10 to 15% natural gas or 3 to 8% propane gas. (The exact amount depends on the surface area to be carburized and on furnace conditions; usually a few trials will establish conditions for rapid carburization without sooting.) If it is desired to hold a definite carbon in the case, this can be done with the equilibrium curves, holding the work for diffusion of the carbon toward the end of the carburizing cycle.

For example, if a 0.050-in. case was specified with 0.80% carbon, a 25° F. dew point would be selected from the 1700° curve. About 6 hr. (depending on furnace conditions) would be necessary. For the first 4 hr. of carburizing, approximately 10% of natural gas would be added to the atmosphere to increase the carbon potential to the maximum. During the last 2 hr. of the cycle, the enriching gas would be shut off and the excess carbon in the case would diffuse inward to the core and outward to the atmosphere (which has previously been set at 25° F. dew point to be in equilibrium with an 0.80% carbon steel when no enriching hydrocarbon is added). Care must be taken to avoid an excessive amount of enriching gas that may cause sooting in the furnace or on the work. This will lower the dew point in the diffusion cycle and the equilibrium condition would not be reached unless the flow of atmosphere was increased to burn out the carbon and a longer time allowed for diffusion.

When carbo-nitriding, another variable, ammonia gas, is added which also shifts the equilibrium curves to higher carbon potentials. The exact shift has not been determined, but studies have shown that 0.80 to 0.90% carbon can be obtained with furnace dew points of 40° F. at 1550 to 1600° F., using endothermic generator gas as a carrier with approximately 5% natural gas and 20% ammonia gas. Lower dew points will result in higher carbon cases unless the natural gas is omitted. For such reasons the equilibrium curves in the data sheet, p. 96-B, are not applicable to carbo-nitriding, but the author wishes to point out that the carbon content can be controlled by adjusting the furnace dew point appropriately.

LIMITATIONS OF EQUILIBRIUM CURVES

Inasmuch as our studies were carried out in a furnace of industrial size, the data presented in this article should be reliable when applied directly to practice. The curves have been verified during the past year by day-to-day operations in several large heat treating departments throughout the country. One bolt manufacturer immediately adapted the curves for carbon restoration work in large conveyer furnaces. In a recent check the curves for plain carbon steels were used in the heat treatment of boron steels. Samples and long stringer-type steel turnings were run for 6 hr. at 1650° F. with a dew point of 45° F., to produce a 0.40% carbon as shown in the data sheet. After this prolonged treatment, turnings analyzed 0.37% carbon, and the change-in-weight samples showed equilibrium. The high-carbon end of the curve was then checked by repeating the experiment on the same steel turnings at 1650° F. for 6 hr. with a dew point of 21° F. The 40% carbon increased to 1.00% carbon. The carbon analysis of the chips showed 1.04%.

This test not only verified the reliability of the curves for long cycles, but also showed that the straight carbon steel curves could be applied to low-alloy steels of the boron type. The author does not wish to leave the impression that the equilibrium curves are infallible, but merely that they have been carefully checked in industrial heat treating applications.

If a discrepancy does show up when applying the curves, the following points should be carefully investigated:

Precautions in Using the Curves

Sampling Method – As emphasized throughout this article, the dew point must be taken from the furnace. The sampling tube must be a high-alloy pipe or tube, preferably Inconel. Ordinary steel or low alloy will oxidize and cause erroneous readings. If the sampling tube is to be a permanent one, the tube should extend well through the furnace wall so its temperature will not be affected by the refractory lining. Keep the end as close as possible to the work. For spot checks, a sampling tube can be inserted through a peepsight or a small hole and placed near the work. Never leave the door open when taking dew points. Make sure that abnormally high dew points which occur on starting up equipment do not form condensate in the sampling line.

Dew Point Instrument – The old method of checking dew point by the appearance of fog on a cold mirror is not reliable. In the low range, an operator can easily be from 10 to 20° F. off due to supercooling. Even trained technicians will not agree with one another's results. An instrument should be selected that can be operated by any shopman, and each man using the instrument should be able to check each other's results. A good practice is to keep two instruments available for cross checking. If an instrument is in error, it should be sent back to the factory for service and calibration.

Atmosphere Generator – The equilibrium curves apply only to a completely reacted endothermic generator gas with analysis as listed in Table I, p. 91. All our data for the curves were obtained using a Lindberg "Hyen" endothermic generator, but they should apply to any other manufacturer's endothermic generator provided the gas is completely reacted. Methane should not exceed 1.5% at such low dew points as 10° F. and carbon dioxide should be zero under these conditions. If the methane exceeds 1.5% and there is also carbon dioxide in the gas, then it is not completely reacted and the equilibrium curves will be incorrect. If an analysis shows that the generator gas is not completely reacted, a new charge of catalyst may be required – or it may be possible that the generator is not designed to operate at high cracking efficiency.

Type of Gas Being Cracked – Although natural gas was referred to in this article as an ideal fuel for cracking, propane or city gases can be used. Unsaturated hydrocarbon impurities in propane – such as propylene or butylene – should not exceed 5%. If such impurities exceed 10%, considerable soot will deposit in the generator when it operates at low dew points. If the 95% natural propane is used, a completely reacted gas will result. Hydrogen and carbon monoxide will vary a few percent from the analysis shown in Table I for natural gas, but spot checking when feeding propane to the generator does not seem to alter the equilibrium curves. Residual hydrocarbon is methane, as when cracking natural gas. Adjustment of the air-gas ratio to produce a definite dew point is more critical when using propane than when using natural gas. City or manufactured gas can be used for cracking, but these gases vary so much in chemical analysis, especially in winter months, that control of the air-gas ratio to produce a definite dew point is very troublesome; propane would be preferable for applications where dew point control is critical.

Enrichment of Endothermic Gas – As pointed out when discussing carburizing action, enrichment of the atmosphere with natural gas or propane will shift the equilibrium curves to a higher carbon potential. Enrichment with ammonia will likewise shift the equilibrium conditions, and the curves in the data sheet can only predict the general shift. Care should also be taken to burn any excess carbon out of the furnace refractories by periodically shutting off the atmosphere and introducing air. Carbon precipitation at low furnace temperatures may interfere with dew point control at high furnace temperatures.

Surface Condition of the Steel – The equilibrium curves may not apply if there is excessive scale on the work. Heavy forging scale or mill scale will be reduced, but this leaves a spongy barrier of iron that may interfere with the diffusion of carbon into the steel. Iron oxide also acts as a catalyst to break carbon monoxide down into soot and carbon dioxide. A little free carbon may cause a higher carbon potential in the atmosphere surrounding a clean steel surface and actually carburize it unexpectedly.

Control of the dew point within ±5° F. in all types of furnaces is not always an easy matter. Nor is it an easy matter to control endothermic generators to definite dew point, particularly if the gas pressure varies. At temperatures exceeding 1700° F. dew point must be controlled to ± 1° F. required for equilibrium conditions with straight carbon steels in excess of 0.50% C – too close to be practical at the present time. Fortunately the only commercial operation on straight carbon steel above 1700° F. is copper brazing, where the time cycle is

(Continued on p. 172)

Ingersoll-Rand uses Nickel Alloy Steel Gears

A size 20 Ingersoll-Rand Multi-vane close-quarter drill reaming a one inch hole in a machine bed plate casting. Extremely close quarter operations on much of today's modern machinery has created a demand for powerful tools capable of getting into narrow corners for such operations as drilling and reaming of holes. And it poses the problem of getting gears which are small enough for the job, yet tough enough to transmit high torques. Ingersoll-Rand Company engineers specified a nickel alloy steel for the bevel gears and pinions in that company's pneumatically operated close-quarter drills.

For Increased Strength . . . Heavier Loads . . . Longer Machine Life

Maximum wear resistance . . . greatest surface compressive strength . . . extremely tough cores that withstand shock loads as well as fatigue and bending stresses . . .

These are some of the properties you get in gears fabricated from *nickel alloy carburizing steels.*

Furthermore, distortion that accompanies heat treating . . . a chief cause of noisy gears . . . is inherently resisted by nickel alloy carburizing steels.

Direct hardening nickel alloy steels are used for gears carrying heavy tooth loading in applications where resistance to wear and surface compressive stresses is not quite so vital a factor. Here again, the nickel-containing steels develop the required strength more consistently and in heavier sections than carbon steels, and are generally more resistant to shock, fatigue and multi-axial stresses. Distortion resulting from heat treatment may be minimized by using nickel alloy steels. And, their machinability before final heat treatment is very good.

When you face revised stress analysis due to design changes . . . or changed fabricating methods that demand improved response to heat treating . . . remember that the many standard grades of nickel alloyed steels permit specifying the particular type which provides the best set of properties for any reasonable fabrication and service demands.

Investigate all the benefits nickel alloy steel gears can give you. Send us details of your problems for our suggestions.

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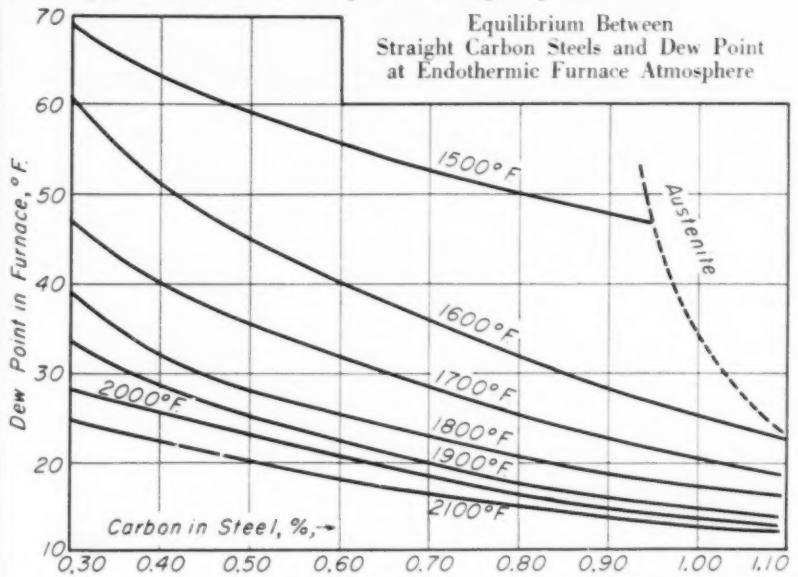
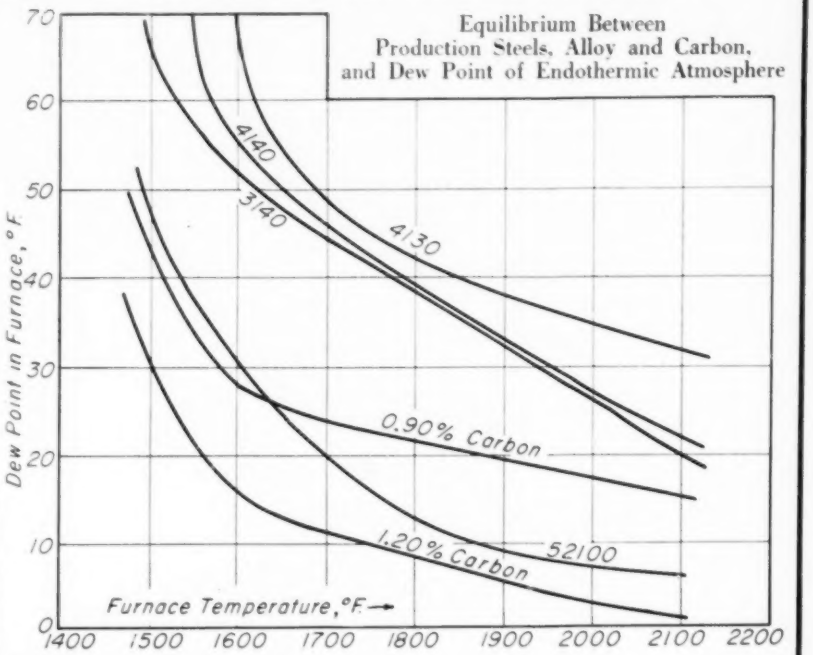
Equilibrium Between Steels and Dew Points of a Prepared Furnace Atmosphere

By Norbert K. Koebel

For analyses of endothermic atmospheres, see Fig. 2, p. 92.



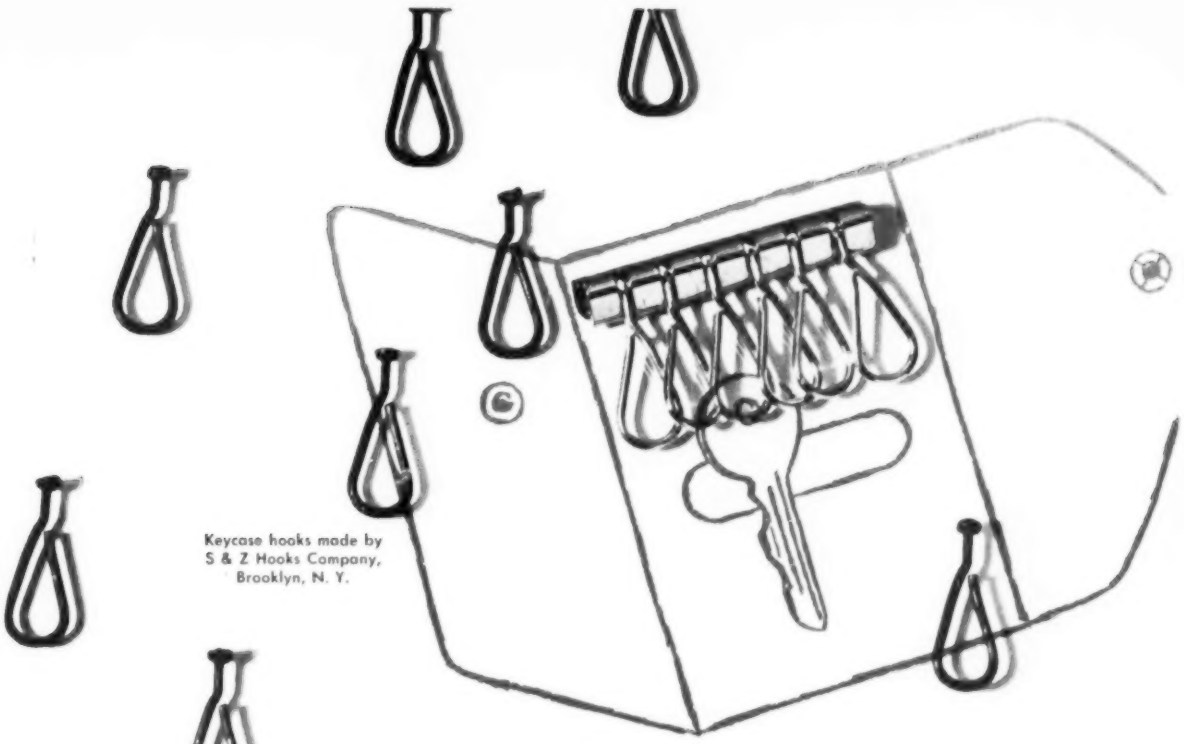


Dew Point Temperature in Furnace Using "Hyen" Endothermic Atmosphere for Hardening Some Common Types of Toolsteels

Type	Nature	Typical Steel	Furnace*	Minimum	Equilibrium†	Maximum	Type
IV-B	Cr-W-Mo hot work die steel	Vanadium-Alloys' Hotform	1850° F.	40° F.	46.5° F.	54° F.	IV-B
IV-A-2	5 Cr, 1Mo, 1C, air hardening	Braeburn's Airque	1750	40	45	50	IV-A-2
III-B	Si-Mn shock resisting chisel steel	Carpenter's Solar	1550	40	52.5	60	III-B
II-A	Mn nondeforming, oil hardening die steel	Latrobe's Badger	1450	45	50	55	II-A
II-C	High-carbon, high-chromium, oil hardening	Allegheny Ludlum's Huron	1750	20	—	70	II-C
III-D	Low-tungsten, chromium chisel steel	Allegheny Ludlum's Seminole	1750	40	42	45	III-D
II-D	High-carbon, high-chromium, air hardening	Vanadium-Alloys' Ohio Die	1850	20	—	70	II-D
VI-K	Tungsten fast finishing steel	Carpenter's KW	1550	23	27	33.5	VI-K
I-C	C-V shallow hardening die steel	Crucible's Alva	1500	45	50	55	I-C
II-A-3	High-carbon, low-tungsten, oil hardening	Allegheny Ludlum's Utica	1550	25	31.5	36	II-A-3
VI-F	Cr-Ni-Mo toolsteel	Carpenter's R.D.S.	1500	50	60	65	VI-F
V-C-1	18-4-1 high speed	Crucible's Rex AA	2350	0	8.5	10	V-C-1
V-A-2	5-5-5 W-Cr-Mo high speed	Bethlehem's HM	2250	5	12	15	V-A-2

*Appropriate mid-range of hardening temperature for the type.

†Temperature for equilibrium dew point.



Keycase hooks made by S & Z Hooks Company, Brooklyn, N. Y.

AEROCARB® Carburizing Compounds give spring steel properties to low carbon steel

METRO HEAT TREAT COMPANY, with plants in New York City, Englewood, and Ridgefield, N. J., had a problem which AEROCARB Carburizing Compounds solved very nicely:

S & Z Hooks Company wanted to make keycase hooks economically from low carbon steel, since using spring steel would involve costly die wear and expensive high pressure forming. Could Metro treat the low carbon hooks and give them spring steel properties?

Metro said they could, and they did — after intensive study and experimentation.

They found that salt bath carburization would be required, but they were unable to get the desired properties — long bath life, proper spring tension — until they tried AEROCARB Carburizing Compounds.

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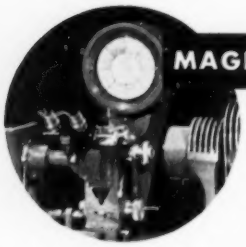
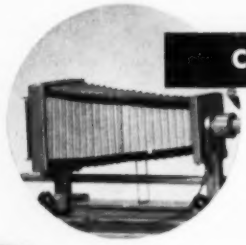
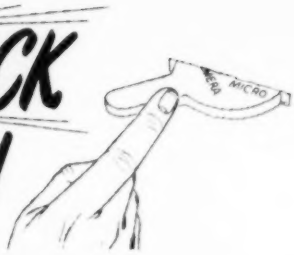




...AT THE FLICK OF A SWITCH



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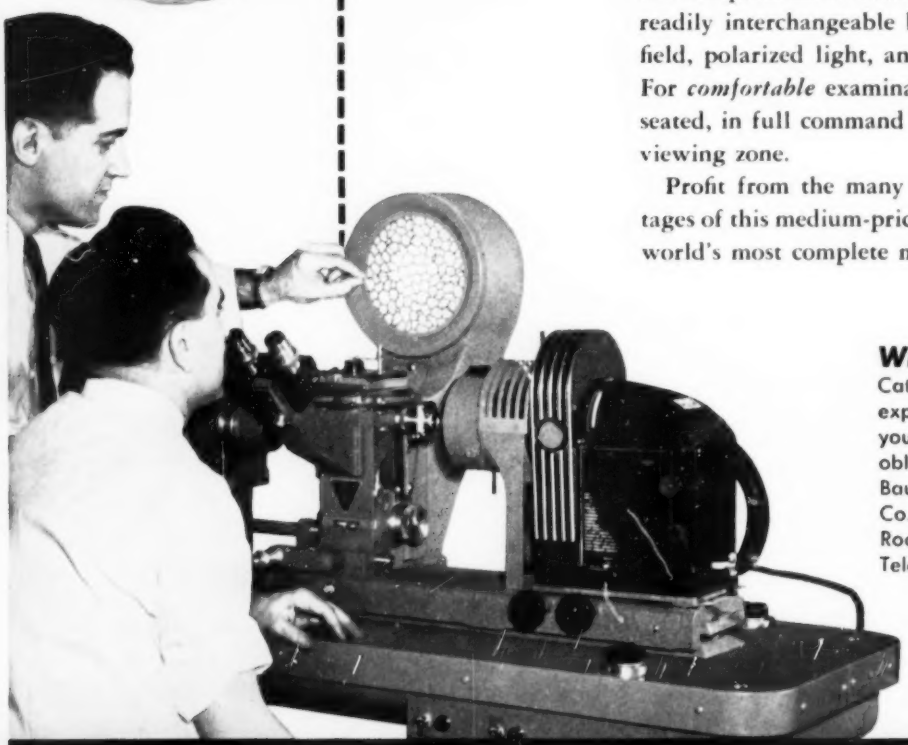

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By BURNS GEORGE
Vice-President in Charge of Sales
Vanadium-Alloys Steel Co., Latrobe, Pa.

The Quality of Toolsteel — Historical Development*

IF TUBAL-CAIN could return to our world he would observe quite a change in the quality of tool materials — even those used for cutting stone. Tubal-cain was the world's first metallurgist. In fact, he was the world's first professor of metallurgy. In Chapter IV of the Book of Genesis it states he was "an instructor of every artificer in brass and iron". Tubal-cain was only seven generations removed from Adam — proof that the value of iron was early appreciated.

I wish we knew more about the men of early days — the men who produced the Wootz steels of India, Damascus steels of Syria, and Toledo steels of Spain. Throughout prehistoric and ancient history up to the present day, iron and its alloys have been the most important tool materials. In addition to weapons (which can quite accurately be classed as tools), the ancients used iron and its alloys for chisels, axes, scythes, augers, hammers and saws. Much iron was needed for building King Solomon's temple, for instance. More than 150,000 workmen had to be supplied with tools on that job. I have often thought that if toolsteel salesmen were prevalent in that day they must have clamored over that contract as persistently as our competitors work on the good accounts today.

Another big job must have been the pyramids. Historians speak mostly of bronze tools for those contracts, but I'll bet some iron — meteoric or otherwise — was used because an iron sickle blade was found under the base of one of the pyramids.

Toolsteel salesmen didn't have it all their own way, though. No one has traced cemented carbides back that far, but saws for cutting stone were made of bronze with diamonds or other hard gems set into the cutting edges. A pretty smart piece of tool engineering, if you ask me.

It would be unfair to compare the quality of present-day toolsteels with that of the ancients, of course. We have benefited by many inven-

*The annual McFarland Lecture presented before the Pennsylvania State Chapter ASM on May 8, 1953. In two parts, the second, to be published in a later issue, will cover some of the current practices in quality toolsteel manufacture.

tions and developments in science and mechanics outside the field of metallurgy. Chemical analysis is one example; the invention of the lens and the microscope, steam and mechanical power and electrical power are others. A lot of things had to be invented before someone could build an automobile and before the present quality of steel could be attained.

Probably the first iron came from meteors. Tools were first made of stone; what more likely than for someone to find a "heavy" stone (a meteor) and discover that it worked better for tools? The next step might be the discovery that the heavy stone could be heated and shaped. In the course of heating, some carburization was inevitable through contact with carbonaceous materials such as charcoal, bone, or coal, and thus some control of hardness was developed.

Meteors must have been pretty hard to find (as they are today) even though around Joshua's time there was a sudden abundance, to the dismay of the people of Jarmuth. In the search for meteors some observant fellow evidently discovered an ore of iron – perhaps magnetite – which he recognized because it was heavy. He must have been pretty excited when he hit that small ore deposit. But the elation of that first fellow must have quickly changed to dismay when he found that, unlike the heavy "stone" of the meteorite, his stone crumbled to pieces when heated. However, someone in the tribe discovered how to reduce the stone to produce cast iron, and an industry was born.

Along about 1000 to 1500 B. C. it was flourishing pretty well. Archeologists have uncovered an arsenal in the palace of Sargon II, a king of Assyria, dated about 700 B. C., which contained more than 200 tons of iron implements. Enough iron was available in King David's time (about 1055 B. C.) so he could use it for nails and door hinges for the temple.

The early artisans learned how to malleableize the cast iron and how to remelt it in crucibles. The Wootz steels of India and the Damascus steels of Syria were apparently melted products, produced as long ago as 325 B. C. They were world famous, as were the Toledo steels of Spain. Used mostly for swords and weapons, they were heat treated to give strength, toughness and hardness.

Most ancient steels available for examination, however, are nonuniform in texture and in hardness. The Damascus blade displayed by Vanadium-Alloys Steel Co. at the National Metal Show a few years ago varied in hardness from Rockwell C-10 to about C-47 in closely adjoining areas. Many old steels are made up from small pieces welded together, leaving streaky nonhomogeneous structures exactly similar to the "shear steels" produced in England at a much later period.

Some of the heat treatments developed by those old-timers were novel and gruesome – the quenching of swords by plunging the heated blade through the body of a slave, is well known as one of their "secrets". Before we smile too broadly, however, let me tell you that only a few years ago, and within 60 or 70 miles of this seat of learning, I found a heat treater putting urine in his quench tank to get better performance from cold heading dies. I told him it was okay with me if he could stand it, but that I thought he'd do just as well if he put a little salt in the water.

There are those who believe these old-time steels have never been equaled; that they possessed some peculiar properties which no present-day metallurgist has been able to discover. That sort of poppycock makes me mad. It's in the same class with the guy who tried to get me to buy his wares by offering a free gift of razor blades "made from the finest Swedish steel" – the inference being that no steel equals Swedish; it's in the same class with the charlatans who roam the country selling secret heat treating processes or aids that will (in some mysterious manner impossible for metallurgists to determine, of course) make carbon steel the equal of high speed steel in performance. There are always enough suckers to believe these yarns and keep the fakers in business by buying their black powder at five or ten dollars per pound.

But knowledge of crucible melting *was* lost during the Dark Ages and not rediscovered until about 1740. Until then toolsteel quality in England was represented by "blister steel", "shear steel" and "double shear steel". Blister steel was the product of heating wrought iron in contact with charcoal to produce a carburized material that would harden to a shallow depth. When forged into thin sections, sheared to short lengths, bundled and welded for reforging, it produced shear steel. The same operation repeated twice yielded double shear steel.

Crucible melting, invented by Huntsman and refined by David Mushet, gave us a toolsteel of vastly improved uniformity. It was practiced in this country as late as 1930. In 1928 we were still producing a carbon-vanadium toolsteel known as Colonial No. 7 that was justly famous for its uniformity of response to heat treatment. We did this by using muck bar (a form of

wrought iron) as a melting base, and carefully following the same practice down to purchasing crucibles always from the same source. By careful duplication of the practice we were able to produce steel that responded to heat treatment exactly the same about 50% of the time. When we switched to electric furnace melting of this grade, through knowledge of slag control, deoxidation practice and other factors, we were able to use ordinary scrap as a melting base at great savings in cost.

Before considering the contribution of the electric melting furnace to toolsteel quality, there are a few things it is well to keep in mind. It is mighty interesting that, up to about 1857 or 1860 – less than 100 years ago – steel was used almost entirely for tools. Wrought iron or cast iron was used for construction purposes, including such things as rails and steam boilers. Steel did not become available for construction purposes until after the invention of the bessemer and openhearth processes, and the first steel bridge was not built in America until 1890. It is also interesting to note that neither the bessemer nor openhearth process has figured much in the production of toolsteel.

Furthermore, until about 1895 to 1900 there were only two kinds of toolsteel – plain carbon and Mushet's self-hardening steel, the forerunner of high speed steels. Today, in our own factories, we produce more than 100 different compositions. Some experimenting with alloys of iron and chromium and iron and nickel was done as early as 1820, I believe by David Mushet, who must have been the father of Robert Mushet, the inventor of the tungsten self-hardening steels. These men also experimented extensively with manganese in steel without much marketing success. Hadfield produced the 13% manganese steel bearing his name in 1884, but it came to be used more for service parts than for tools.

So we came into the 20th century with two toolsteels – a cinch for the salesmen of that day. Taylor and White's experiments which resulted in new methods of heat treating high-alloy grades added further impetus. By 1910 the self-hardening steel composition had given way to 18% tungsten, 4% chromium steel, which a little later was improved by adding 1% vanadium.

Properties of toolsteel are basically dependent upon their chemical composition. If these properties are also a part of toolsteel quality – and I think they are – then a great deal has been accomplished since 1910. Carbon toolsteels in those days were graded for quality on the basis of fracture and carbon content. Today they are more scientifically graded on the basis of chemical analysis, penetration of hardness, and fracture grain size. Carbon-vanadium steels are available on the same test basis with the added grain refinement imparted by vanadium. Chromium-vanadium toolsteels harden with a tough, soft core, but to a greater depth than carbon and carbon-vanadium steels. They are made in carbon contents from 0.40 to 1.10%.

A whole series of die steels for cold work has come into use since about 1908, all designed for specific applications. One of the most widely used of this series is the manganese oil hardening die steel. Containing 0.85 to 1.20% carbon (depending upon the producer's interpretation of the qualities desired), it derives its properties chiefly from the presence of manganese which lowers the critical range of the steel and makes it possible to obtain file hardness by oil quenching, as against water quenching for the carbon steels originally used. Chromium, tungsten and vanadium are sometimes added for further refinement of properties. Manganese oil hardening steels, often called "nonshrinking" steels, were developed to reduce susceptibility to cracking and movement in hardening.

The 5% chromium types of air hardening die steels for cold work contain about 1% C, 5% Cr, 1% Mo, and 0.25 to 0.50% V as the principal alloying elements. They harden fully when cooled in still air and move in hardening still less than the manganese oil hardening types. They also have better wear resistance and toughness.

One of the important die steels for cold work is the high-carbon, high-chromium steel containing from 1.50 to 2.20% C and 12% Cr with or without smaller additions of other alloys. The wear resistance of this steel is about five times that of the 1% carbon toolsteels. The first composition of this type was developed in England by P. R. Kunsman, and a steel bearing his initials as a tradename, "PRK", is still very popular in that country. I well remember melting the initial experimental heats of this analysis which resulted in the grade tradenamed Crocar by Vanadium-Alloys Steel Co. Our experimental melting equipment was a carbon-block resistance furnace which would hold a 50-lb. crucible. Pulling the crucible at the melting temperature was quite a little job and, after a crucible had been used three or four times and grown thin, it was not uncommon for the bottom to fall out and the steel to spill on the floor with an ample quantity of sparks down my shoes. When I did succeed in getting an ingot,

Vanadium Introduced

the hammerman broke it to pieces in short order because we lacked knowledge of how to heat it for forging. I burned my socks off a good many times before we finally succeeded in casting an ingot and forging it into a useful size for test. Modern high-carbon, high-chromium steels can be hardened either by oil quenching or by cooling in still air.

Die steels for hot work developed during the alloy toolsteel era are based principally on tungsten and chromium. Virtually all hot work steels are quite low in carbon; the chromium types usually contain in the neighborhood of 5% Cr with 1 to 2% W, Mo, or both, and with vanadium up to 1%. Tungsten types are based on tungsten contents of 9 to 18%, with chromium from as low as 1.75 to 4%. Thus, a wide variety of properties and qualities is provided. Hot work steels in which molybdenum has replaced tungsten are also produced but have never been widely accepted.

It is not my purpose here to describe these steels or their properties in detail, but rather to show the very great number of steels that are commercially useful. Special-purpose steels based on manganese, silicon, tungsten, chromium, molybdenum or nickel, or combinations of these alloying elements, are very numerous.

Of all the alloy toolsteels, high speed steels are still the most important, and 24 different compositions are being produced today. What a step from the Mushet self-hardening steel available at the beginning of the century! There are tungsten types, molybdenum types, tungsten-molybdenum types, high-vanadium types – all these with or without cobalt – high-molybdenum types and low-molybdenum types.

A great improvement in the quality of all toolsteels resulted from the introduction of vanadium as an alloying element. First added to 18% tungsten high speed steel, it is now found in toolsteels for all purposes and quite generally improves the quality of any steel to which it is added. A major change in the nature of high speed steels resulted from the discovery that a ratio exists between the carbon and the vanadium contents. When an excess of carbon over vanadium is present, the steel becomes very brittle. If vanadium exceeds carbon, the steel cannot be highly hardened. Steels of the 18-4-1 type originally contained 0.60 to 0.65% carbon, which was gradually increased to a maximum of about 0.78%. Beyond this the steel was too brittle to forge or to be economically useful. With higher vanadium content, the carbon could be raised without imparting brittleness, resulting in greatly improved wear resistance and cutting efficiency. This discovery, by J. P. Gill, president of Vanadium-Alloys Steel Co., which holds the patents, has resulted in commercial high speed steels containing as much as 1.50% C and 5% V. Wear resistance is eight to ten times that of the regular high speed steel compositions. With these steels machining speeds have been increased 15 to 100%, and the hardness level of machinable construction steels has also been materially increased.

Roy C. McKenna

Vanadium-Alloys Steel Co. was founded in 1910 by the McKenna Brothers, one of whom, Roy C., became president in 1915 at the age of 32. He was immediately catapulted into a net of intricate business problems which he solved with brilliant success. At the end of World War I Roy McKenna determined that Vanadium should produce the best toolsteel made, and to this end organized a metallurgical department in 1920. Vanadium-Alloys has since become one of the principal toolsteel producers in the country, and has developed many of the improved compositions outlined in this article.

Another contribution to the quality of toolsteel has been the substitution of molybdenum for tungsten. It was found that one part of molybdenum replacing 2 to 2½ parts of tungsten would provide a steel of approximately similar quality. The outcome of this development has been the production of a number of molybdenum high speed steels of varying properties and lower price, with consequent conservation of alloys for defense needs.

Actually, it is not very difficult to invent a new composition of high speed steel these days. You could throw together almost any group of alloys and come up with a steel having some high speed qualities, and some fool would be sure to buy it. It is a pleasant reflection on American industry, however, that only those compositions having distinctive and worthwhile qualities have ever become well established in trade.

Dislocations or What Makes Metals so Weak?

By W. T. READ, JR.
Bell Telephone Laboratories
Murray Hill, N. J.

A RECENT MOVIE by Alec Guinness, "The Man in the White Suit", is the story of a scientist who develops an amazingly strong fabric. Surprisingly enough, the principle he uses is a perfectly sound one and quite simple in theory: Common textile fibers break because they are made up of short molecular chains that pull apart when the fiber is stretched. The fibers or threads in the "white suit", however, consist of very long molecular chains running the entire length of the thread; so breaking the thread means breaking the bonds between atoms, and these are exceedingly strong.

A similar situation exists in metallurgy, especially in the metallurgy of relatively pure ductile metals such as iron, aluminum, copper, tin or zinc. Metals, like textiles, fall far short of the strength to be derived from the forces between atoms. As a simple example take a perfect (and we might emphasize the word "perfect") – a perfect single crystal specimen of a metal, say zinc, having the hexagonal close-packed structure. The atoms are arranged in space in a simple regular pattern (which might be used to stack golf balls in the smallest volume). From our knowledge of the forces between atoms, it is not too difficult to calculate the shear strength, or yield stress, of such a regular array of atoms. The calculation shows that plastic deformation should begin when the elastic strain is somewhere between 1% and 10%!

The facts, however, are quite different. As all engineering students learn, good, single crystals of the ductile metals may begin to deform plastically at strains from 0.001 to 0.01%. In other words, the most nearly pure and perfect single crystals have about one thousandth the shear strength calculated from the interatomic forces *in a regular array of atoms*. Hence, the question posed in the title of this article: "What makes metals so weak?"

The joker seems to be that, in a real crystal, not quite all of the atoms *are* arranged in the regular pattern. Perhaps one atom in every billion or so is not surrounded by neighbors in the characteristic pattern. In other words, there are defects or imperfections in the architecture.

I am going to discuss a particular simple type of defect that limits the strength of metals. The essential feature of this defect is that it moves easily under stress and, in moving, produces plastic deformation. Incidentally, as I will show later, a large density – a fairly large number per cu.mm. – of such defects is more favorable for strength than a small density. This same fact explains why commercial metals (which are relatively imperfect) are stronger than good, single crystals of "pure" metals.

Of the defects that are important in physical metallurgy, perhaps the easiest to visualize is a vacancy – a missing atom in an otherwise perfect crystal. The defects best known to practical metallurgists (in distinction from physical or theoretical metallurgists) are probably impurity atoms and grain boundaries. Figure 2 shows in color, inside the questioned circle, still another example of a defect. I will discuss it in some detail later, but for the present I merely point out that the symbol ⊥ denotes a defect in the arrangement of atoms. Normally the assemblage of atoms (each one denoted by a circle) forms a square array in the plane of the figure,

with each atom surrounded by four nearest neighbors (neglecting atoms in neighboring planes parallel to the one shown). The atom A just above the symbol ⊥, however, is not symmetrically surrounded by neighbors in the characteristic pattern. Since Fig. 2 shows only a cross section of the crystal, it should be remembered that actually the defect runs through neighboring planes in the crystal along a line normal to the surface of the page. This defect is one example of what is called a dislocation.

Strong Crystals – "Whiskers" – Before saying more about dislocations, I would like to relate the story of a fascinating experiment that grew out of some mysterious short circuits in telephone equipment. The story is pertinent because it shows that pure single crystals of tin – which are ordinarily quite soft – can be about as strong as the strongest steel provided they don't have the troublesome defect.

Experience would not lead one to expect to obtain unusual strength by reducing the number of defects, because a fine-grained specimen (with a large number of "misfit" atoms at the grain boundaries) has a greater resistance to plastic flow than a large-grained specimen or a single crystal. Again, it is well known that adding impurity atoms, such as copper in silver, increases the shear strength. A cold worked specimen is harder than an annealed one.

Actually, though, these facts are in accord with the theory of defects. The theory predicts that shear strength should decrease as the density of defects decreases *provided* the total number of dislocations is not zero. (If there were *no* dislocations in a specimen, it should have the strength calculated from the forces between atoms in a perfect crystal; therefore, it should deform elastically up to several per cent strain without plastic flow.)

For about 20 years the "perfect" metal crystal of great strength was – like the "white suit" – a theoretical possibility which interested a few scientists. One of these theoretical physicists who worried about defects and the strength of crystalline solids was C. Herring of the Bell Telephone Laboratories. Herring applied to pure metals an argument that A. A. Griffith had successfully applied to glass around 1920:

Brittle fracture in glass originates at tiny cracks. Griffith reasoned that there would be fewer cracks in a small piece of glass than in a large one; so maybe a *small enough* piece would have *no* cracks. He carried out experiments that proved his theory: Sufficiently small, freshly drawn glass fibers had a fracture strength of about 1,000,000 psi., which is what one would expect from the interatomic forces existing in glass.

Herring, in turn, reasoned that small enough single crystals of metals should show the same effect in yield stress that glass showed in fracture stress. What suggested this idea to him was some tiny crystals of tin which were being studied at the Bell laboratories by S. M. Arnold, and which had grown spontaneously on tin plated condensers in telephone equipment.

The majority of the crystals were about 0.001 mm. in diameter, and in about 9 months they would grow several millimeters long – sufficient to cause short circuits. Because they were so small and were usually knocked off in examining the condenser, it was some time before they were discovered and studied in the laboratory.

Herring and J. K. Galt, an experimental physicist, were curious about the mechanical properties of these microscopic crystals, or "whiskers", as they were called. With a micromanipulator Galt carefully deformed them under a microscope. His results verified Herring's prediction: These whiskers of pure tin deformed elastically up to about 3% strain. (For comparison Galt tested piano wire in the same apparatus and found a maximum elastic strain of 0.5%). In terms of stress the tiny, pure tin single crystals had a yield stress of about 200,000 psi., which is roughly 1000 times the yield stress of normal sized specimens of the same material, and higher than the yield stress of the strongest structural and machine steels.

In view of Galt's results a thorough investigation of defects would seem to be in order. What are the defects that, even in small numbers, can undermine the strength of crystalline solids, either pure single crystals or commercial structural materials? In

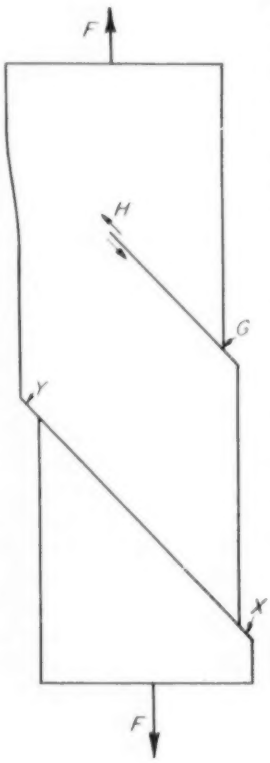

Fig. 1 – Stages of Slip in a Single Crystal. Slip starting at G under influence of force F, progresses along a principal plane in the direction of H. At X-Y a slipped area has extended completely across the crystal

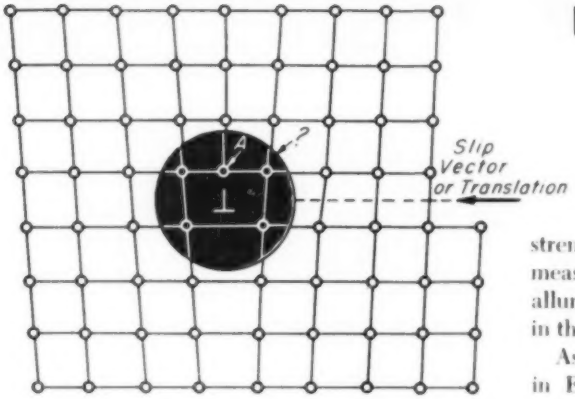

Fig. 2 – Diagram at Atomic Scale of the Advancing Front of a Slipped Area. The slipped area intersects the figure along the dotted line

what follows I shall discuss a few of the basic ideas about defects and in particular about the defect known as a dislocation.

DISLOCATIONS

Six years ago the theory of dislocations consisted of a few simple, ingenious ideas overlaid with a considerable amount of speculation. Today the basic ideas have been firmly established by a few fundamental experiments, of which Galt's is an excellent example. I think that metallurgists will find dislocations not only a fascinating subject but one which can profitably be pursued because of its close relation to technological problems, and in particular to problems of strength and plastic deformation. To bring out the relation between dislocations and plastic flow, I shall introduce dislocations in terms of slip.

Slip – The simplest idea of slip is that planes of atoms slide over one another, like cards in a deck. Usually slip occurs along certain principal crystal planes, such as the close-packed or basal planes in a hexagonal close-packed crystal. Slip is like sliding layers of golf balls over one another in a close-packed stack.

Unit slip has occurred on a slip plane if the adjoining atomic planes, or layers, have been displaced by one interatomic spacing in the direction of slip. After unit slip, the atoms are again in registry across the slip plane; each atom that moved simply has moved into a position previously occupied by its next adjacent neighbor. However, in slipping from one position to the next, the atoms have to pass through a halfway position of maximum misfit in which the normal atom-to-atom relations across the slip plane are severely strained. Such severe distortion of the crystal structure is resisted by the interatomic forces, whose function it is to maintain the normal, regular, symmetrical arrangement of atoms. The interatomic forces provide the shear strength that physicists calculate, which Galt measured in the tiny whiskers, and which metallurgists and designers would like to achieve in the common commercial metals.

Relation Between Dislocations and Slip

As early as 1933, G. I. Taylor and E. Orowan, in England, had postulated what the microscope now verifies – namely, that the deck-of-cards idea of slip is a little too idealized. Slip does not take place simultaneously over a whole slip plane. Rather a slipped area, once started, grows until it covers a whole plane, as Fig. 1 illustrates. In the upper part of the specimen is a slipped area that extends only part way through the crystal. As the slipped area grows and moves into the unslipped region, the specimen gradually yields to the applied tensile stress. Finally slip extends completely through the cross section as shown at X-Y in the lower part of the specimen.

The interesting point here is the head, or advancing front of the slipped area. Between the slipped and the unslipped areas is a more or less well-defined transition or boundary where the slip fades out. This is indicated by the black circle in Fig. 2, and illustrates on an atomic scale the simple case where unit slip has occurred in the slipped area. The slipped area is at the right of the circle and intersects the surface of the paper along the dashed line; the atoms above the dashed line have moved to the left with respect to those below the dashed line, or the ones below the dashed line have moved to the right, or a simultaneous movement of both has resulted in a displacement of one interatomic space. Running perpendicularly to Fig. 2 at about the center of the large circle is a line along which the atoms must depart in some way from the normal arrangement (a square array in the plane of the figure). The colored configuration in Fig. 2 shows approximately how the atoms adjust to the transition between the slipped and unslipped areas. Necessarily, there is a defect here; for example, atom A just above the symbol ⊥ has only three instead of four nearest neighbors in the plane of the figure. This defect is called an "edge dislocation" and is denoted by the symbol ⊥.

Dislocations Are "Line Defects"

Slip is not the only way of forming or visualizing the dislocation. For example, we can think of the dislocation as the edge of a vertical plane of atoms that does not extend through the crystal but ends at the symbol ⊥ – hence the name "edge dislocation". Or we can imagine the dislocation as resulting from removing some of the atoms in a vertical plane, the missing ones lying below the symbol ⊥; the dislocation is called a "line defect" because it lies along a line, which in Fig. 2 runs perpendicularly to the page. So we are in a position to give a general pictorial definition of a dislocation:

A dislocation is a line defect forming the boundary within the crystal of a slipped area.

The boundary of a slipped area is like the boundary that divides a country from its neighbors; the boundary either completely surrounds the country or ends on the seacoast. So a dislocation, which bounds a slipped area, either forms a closed curve or ends on the external surface of the crystal.

When the slipped area grows, the dislocation moves. Conversely, when a dislocation moves, slip occurs in the area that the dislocation moves across, or "sweeps out".

It is not necessary to distort the crystal structure to make a dislocation move; the distortion is already there; we simply move the distorted configuration through the crystal. Hence, a relatively small stress which favors the growth of the slipped area is sufficient to make the dislocation move and the crystal yield. On the other hand, to start slip in a "perfect" crystal (as Galt did) one has to distort the crystal structure severely, and this means overcoming the strong interatomic forces. Thus, even a few dislocations initially present in a crystal are sufficient to explain why it does not have the strength calculated from interatomic forces.

Here one may ask, "Why should there be any dislocations in the first place – before slip begins? Aren't dislocations formed by incomplete slip?" The answer is that dislocations can originate in accidents of growth or solidification, as well as in slip. The care required to grow single crystals, rather than polycrystals, shows how difficult it is to avoid at least some accidents that mar the perfection of the crystal structure. In fact so-called single crystals can be regarded as the limiting case of polycrystals in which the difference in orientation of neighboring grains is vanishingly small. Whether a dislocation was formed during slip or solidification, the dislocation can always be *visualized* as the result of slip – in other words, an as-grown crystal containing dislocations is just the same as a crystal having some slipped areas that don't cover the whole slip plane.

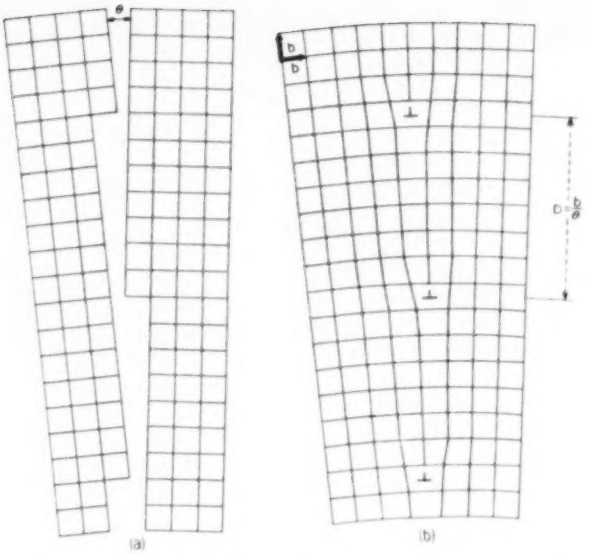

Fig. 3 – Diagram (at Left) at Atomic Scale of Two Crystals That Have a Small Difference in Orientation. If the two crystals are joined (at right) to form a bicrystal, the interface, or grain boundary, is made up of dislocations

GRAIN BOUNDARIES

Later I will take up the question of how the few dislocations initially present can cause an almost unlimited amount of slip. First, however, the relation between dislocations and grain boundaries. I shall show that there is no difference between a single crystal containing dislocations and a polycrystal in which the neighboring grains have almost the same orientation. Again I shall introduce the subject by the story of an interesting experiment at the Bell Telephone Laboratories.

In connection with an extensive transistor* program, an engineer, H. E. Corey, noticed a curious pattern of etch pits on germanium crystals. It was known that etch pits tend to form at defects or severely distorted regions of the crystal, where the normal relations between atoms are already disturbed. Usually etch pits

*See "The Metal Germanium and Its Use in the Electronics Industry", A. S. Rugare, *Metal Progress*, August 1952.

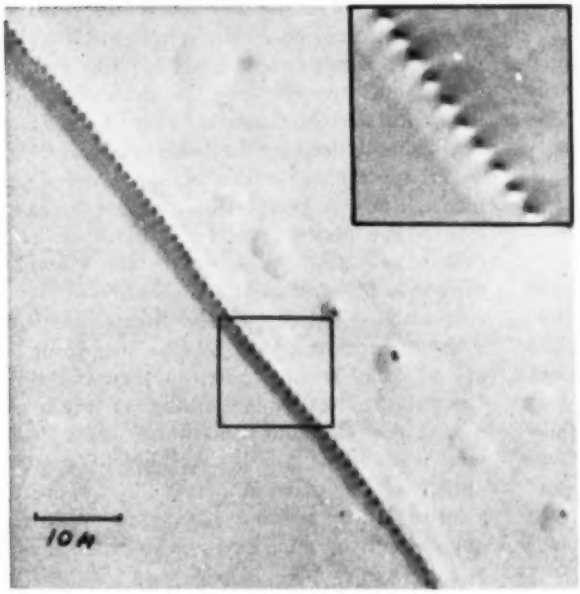

Fig. 4 – Etch Pits in a Surface of Pure Germanium, Representing a Succession of Dislocations Within a Crystal Such as Shown in Fig. 3b. Photograph by E. E. Thomas

are attributed to random surface defects. The curious thing about Corey's pits was that, if he removed a layer of material and re-etched, pits appeared in the same, or at almost the same places. He concluded that they were caused by defects which ran on into the interior of the crystal – in other words, by "line defects". Furthermore, the germanium crystals that showed a large density of pits had electrical properties which suggested defects inside the crystal, and Corey guessed that the defects might be dislocations. If this were true, it was exciting news since it provided an easy way of locating individual dislocations.

Corey's etch pits were identified as dislocations by two metallurgists, W. G. Pfann and F. L. Vogel, who were studying certain boundaries or sub-boundaries in germanium where the orientation difference was about a minute of arc. (Grain boundaries with small angle-of-misfit are, in fact, only a special array of dislocations, as the following argument will show.)

In Fig. 3a we see two crystal grains. Both have the same structure and almost but not quite the same orientation. Now suppose, as in Fig. 3b, the two grains are joined to form a single crystal, or rather a bi-crystal containing a grain boundary. On the interface the atoms adjust their positions and, on the whole, effect a smooth transition from one grain to the other with a comparatively small elastic distortion of the normal crystal structure. However, some planes of atoms necessarily end on the interface, or grain boundary, and where a plane ends there is a defect. These defects form the edges of atomic planes and may be recognized as "edge dislocations" like the one in Fig. 2.

The orientations of the two grains and the grain boundary determine exactly how many planes of atoms end on the boundary; the spacing between dislocations can in fact be calculated from the measured orientations. When the angle of misfit Θ is small, the distance D between dislocations is given by $D = b/\Theta$ where b is the interatomic spacing and Θ is measured in radians.

When the angle of misfit Θ is large enough that the dislocations are no more than one or two interatomic spacings apart, then the individual character of the dislocations is obscured, and it is proper to regard the grain boundary as a continuous interface where the grains don't fit together properly. On the other hand, when Θ is so small that there are only a few dislocations on any given boundary, then the individual character of the grains is lost and it is more meaningful to regard the specimen as a single crystal with some dislocations scattered through it.

Pfann and Vogel were acquainted with both the Corey etch pits and the dislocation theory of grain boundaries (which had been extensively developed at the Bell laboratories by W. Shockley and myself following some pioneer work of J. M. Burgers in the Netherlands and Sir Lawrence Bragg in England). They realized that, if Corey's etch pits really formed at dislocations, then one of their small-angle boundaries should appear as a row of etch pits and the spacing between pits should be equal to the spacing between dislocations. Using an ingenious X-ray technique, Vogel undertook the difficult job of measuring the small angle of misfit of a number of boundaries in germanium like the one illustrated in Fig. 3b. Figure 4 shows the etched surface of one specimen. As predicted, the boundary appears as a row of evenly spaced pits. In all specimens the spacing between pits was that calculated for the spacing between dislocations.

In even the most carefully grown germanium crystals, Vogel finds at least a few etch pits.

"Active" Slip Planes Are Few

Thus there is direct evidence that a few initial dislocations exist – enough to explain why plastic flow begins at a much lower stress than that calculated for a perfect crystal.

WHY IS SLIP CONCENTRATED ON A FEW PLANES?

Although the low stress at which slip begins was explained in 1933 by Taylor and Orowan, the continuation of easy slip beyond the initial yield was not explained until 1950. In 1900, Rosenhain had observed that movement was concentrated on certain active slip planes. Perhaps every thousandth plane slips by a thousand atomic distances – the other planes don't slip at all. How can the few dislocations originally in a crystal give rise to so much slip and why should the slip be concentrated on a few active slip planes?

To answer this question, it is necessary to say a bit more about dislocations in general. So far I have discussed only dislocations that lie along straight lines. Figure 5 illustrates the next simplest case – a dislocation that goes part way through the crystal along a broken line consisting of two straight segments. The figure shows how slip could form such a dislocation; here a slip has occurred – not on a single plane – but on parts of two planes. The slipped area is the area A B C D E F. The boundary (the end within the crystal) of the slipped area is the sharply bent line C D E. Thus by definition C D E is a dislocation. Looking into C D from the right or down E D from above, we would see the same arrangement of atoms as shown in Fig. 2.

The bent dislocation C D E forms the basis of what is called the "Frank-Read mechanism". It explains in a simple way how a large amount of slip can occur on a relatively few active slip planes. A detailed explanation requires a number of drawings showing the deformation of the crystal and the positions of the atoms. Here I will simply describe the basic principle.*

Perhaps the basic idea of the Frank-Read mechanism can best be approached by contrasting the motion of the bent dislocation with that of a straight dislocation – for example, the one in Fig. 2. When the dislocation in Fig. 2 moves across the slip plane from right to left, it produces unit slip in the area swept out or moved over. To accumulate a thousand slips (or a slip of 1000 atomic distances) would require a thousand unit dislocations, and a thousand dislocations couldn't possibly be present initially on one plane in a crystal. Yet to create a lot of dislocations out of nothing would require about the same stress as to produce slip in a perfect crystal.

How, then, can there be a thousand unit slips on one slip plane? The bent, or L-shaped dislocation, C D E in Fig. 5, gives the answer. Perhaps an analogy will be helpful.

When the hand of a clock rotates about its stem or shaft, it sweeps over the whole face of the clock once per revolution. By making a thousand revolutions it sweeps over the whole area of the face a thousand times. The hand and stem together form an L, like the dislocation C D E in Fig. 5, wherein C D could be the "hand" and D E the "stem".

Just as the hand of a clock rotating about

(Continued on p. 168)

Fig. 5 – Diagram Showing a Dislocation That Lies Along a Broken Line Consisting of Two Straight Segments E D and D C at 90° to Each Other.

Fig. 6 – Early Stage in "Frank-Read Mechanism" Wherein the Section D C of Dislocation Is Rotating About Its Inner End. Fig. 7 – Later Stage Wherein D C Has Swept Over All of the Slip Plane A B C D and Upper Part of Crystal Has Slipped One Atom Spacing Relative to Lower Part

*A detailed account is given in my book, "Dislocations in Crystals", published by McGraw-Hill, New York.

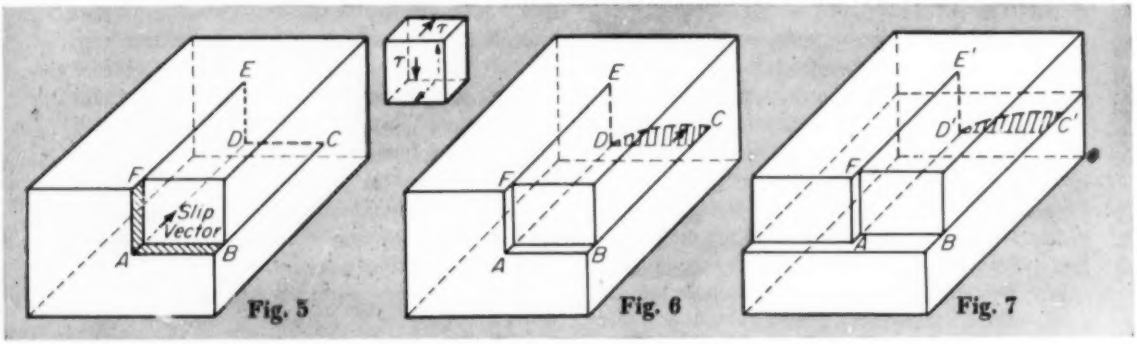

Fig. 5 Fig. 6 Fig. 7

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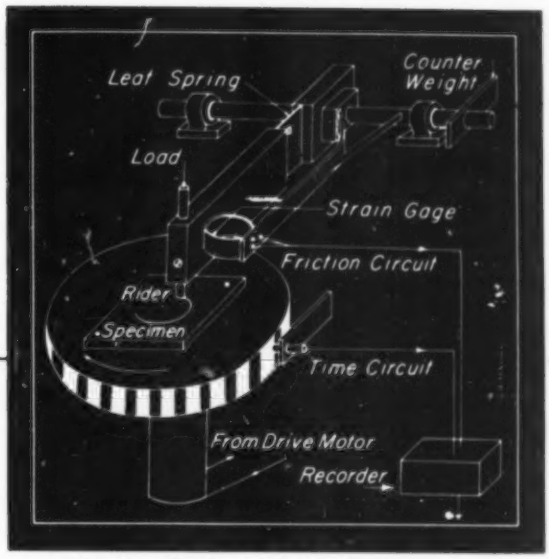

Fig. 1 — Sketch of Friction Apparatus

Frictional Properties of Titanium and Its Alloys

THIS INVESTIGATION was undertaken as a result of reports that the metal titanium shows anomalous frictional properties. Severe galling and metal transfer were noted in sliding applications, and high rates of wear in the related operations of cutting, drawing and grinding. Accordingly, a study was made of the factors associated with the sliding of titanium so as to obtain data on friction and wear which would help in evaluating the usefulness of titanium in such applications.

FRICTION TESTS

The friction apparatus used in the investigation is shown in Fig. 1. It employs a ¼-in. diameter rider having a hemispherically shaped end which contacts a flat specimen mounted on a steel turntable. The rider, which is loaded by a dead weight, is held by a supporting arm that is free to deflect with the frictional forces acting on the rider, and in turn these deflections act on a strain gage. Both the change in resistance of the strain gage due to the friction force, and the change in resistance of an interrupter mechanism on the rotating disk, are displayed on a Sanborn 2-channel recorder.

The slider was cleaned on a fine emery paper while it was rotated in the chuck of a drill press. The flat was cleaned by lapping on fine emery paper, and tapping lightly to remove any loose emery grains on the surface.

A load of 1000 g. was used. Because of the geometry of the surfaces, the area of contact is produced by plastic flow as the load is applied, and hence the average pressure on the sliding surfaces is equal to the flow pressure of the softer metal present in the sliding combination. Low sliding velocities (0.1 to 1 cm. per sec.) were used so as to avoid the complicating effects of frictional heating.

For most of the tests, a commercial grade of

*The research on which this paper was based was carried out under contracts No. 51-1185c and 53-213c, Bureau of Aeronautics, U.S. Navy, to whom the author is indebted for permission to publish this work. It is with pleasure that he thanks Prof. B. G. Rightmire for his encouragement and guidance, and L. Wharton who carried out much of the experimental work.

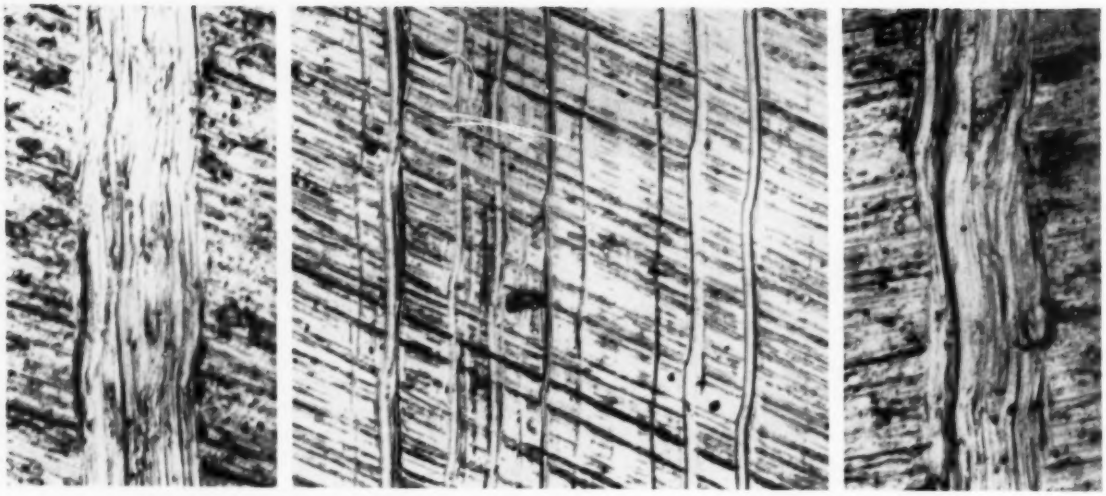

Fig. 2 – Wear Track for Titanium Sliding on Titanium (Left), Titanium Sliding on Steel (Center), and Steel Sliding on Titanium (Right). Unlubricated, 1000-g. load. 200 ×

titanium (RC-70) was used. The low-carbon steel used for comparison was of approximately the same hardness.

TECHNIQUES FOR MEASURING METAL TRANSFER

For these experiments the hemispherically ended slider was made radioactive by irradiation in the nuclear pile at Brookhaven. Using steel, radioactive isotopes of iron with half-lives of 47 days and 2.94 years are produced. Radioactive isotopes of titanium of reasonably long half-lives cannot be obtained in this way, but commercial titanium (Ti-75 A) contains impurities which become radioactive. The activity of 10 microcuries per gram* present more than one month after the end of a four-week irradiation at a flux of 4×10^{11} neutrons per sq. cm. per sec. proved sufficient for measuring the metal transfer. Much higher activities can be obtained by using titanium specimens containing alloying elements such as chromium.

The radioactivity transferred to the flat specimen by the sliding rider was measured by placing the former on an X-ray film and exposing for one week. Blackened patches corresponding to the transferred fragments were produced on development of the film. For quantitative measurements, the amount of blackening was compared with that of a known specimen of the same radioactive metal exposed for a known time.

Results With Unlubricated Surfaces – Figure 2 shows typical friction tracks for titanium (RC-70) on titanium, titanium on steel, and steel on titanium, respectively. The track shown at left is typical for a clean metal slider on a flat surface of the same metal; the deep grooving and the irregular nature of the track are caused by the welding and breaking of metallic junctions as sliding proceeds. The center micro shows much less surface damage, and the fine regular scratches are typical of the sliding of unlike metal combinations, with the asperities of the titanium ploughing through the steel surface. The one at right, however, in which the metal combination is the same as that in the center but with the roles of flat and of slider reversed, is quite different, and instead bears a very close resemblance to the view at left. The explanation is that when sliding starts, so many titanium fragments are transferred to the steel surface that it becomes completely covered, and hence after sliding has proceeded for a very small distance (about 1 mm. as shown by experiments using radioactive steel sliders), the sliding surfaces are both titanium. However, with the titanium rider on the steel

*The microcurie is a term used in nuclear physics to denote 3.8×10^4 disintegrations per second.

Table I–Coefficient of Friction and Metal Transfer for Unlubricated Surfaces

Combination*	Coefficient of Friction (f)	Metal Transfer Rider to Flat, G. per Cm.
Ti on Ti	0.47	25×10^{-7}
Ti on steel	0.25	10×10^{-7}
Steel on Ti	0.47	$<0.005 \times 10^{-7}$

*Clean surfaces, 1000-g. load and velocity of 0.1 cm. per sec.

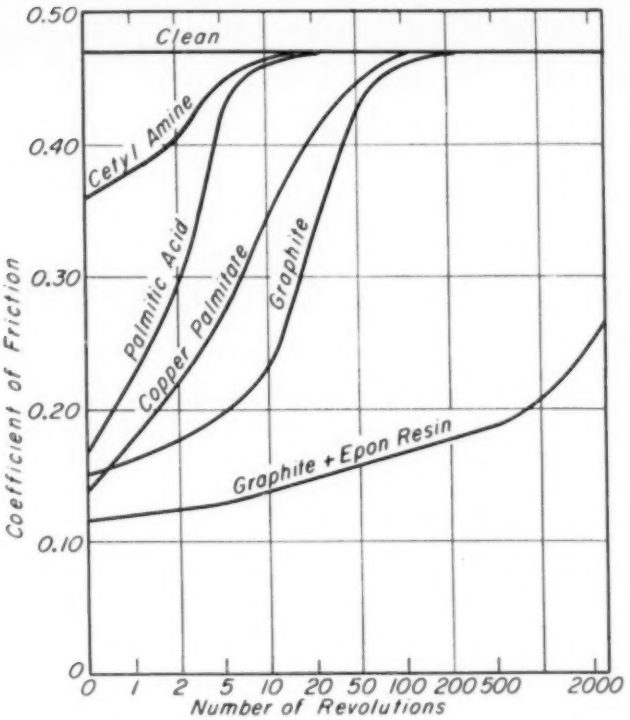

Fig. 3 – Coefficient of Friction for Titanium Sliding on Titanium, Variously Lubricated, Expressed as a Function of Number of Revolutions

flat a different geometry is produced, and this phenomenon does not occur. The coefficient of friction (f) and the amount of metal transferred for these three combinations of unlubricated surfaces are reported in Table I.

The friction coefficient of titanium on titanium is rather low (steel on steel is 0.53; copper on copper, 1.1; titanium on titanium, 0.47), and the wear, too, is low (steel on steel and copper on copper are 70 and 100×10^{-7} g. per cm., respectively, compared with 25×10^{-7} g. per cm. for titanium on titanium.) This suggests that the oxide layer on the titanium surface is not completely broken up during sliding and that much of the sliding is of oxide on oxide. The friction coefficient for steel on titanium was nearly the same as for titanium on titanium, and after the initial adjustment period there was no evidence of steel fragments being transferred to the titanium surface. This confirms previous deductions that the steel slider becomes completely coated with titanium fragments.

The friction results for titanium on the steel flat are fairly normal. The amount of wear is rather large (copper on steel, 5×10^{-7} g. per cm.; steel on copper, 3; titanium on steel, 10). This result is in agreement with the experiments of Wooster and MacDonald (*Nature*, Vol. 160, 1947, p. 260) on the ease with which titanium welds to various minerals. It may be that, on occasion, the titanium surface layers themselves are able to form strong welds with other metals.

Other hard metals, such as copper, brass and tungsten carbide, behave similarly to steel when slid against titanium and soon become coated with titanium fragments. Softer metals such as zinc and lead, on the other hand, smear onto the titanium and soon cover it.

Liquid Lubricants Ineffective

Results With Lubricated Surfaces – Table II shows the friction coefficients for titanium on titanium lubricated by various solids and liquids. For comparison, values for steel on steel, measured under the same conditions, are also shown.

It will be seen that none of the liquid lubricants has in any way lowered the coefficient of friction. This unusual effect, sometimes observed with unreactive metals like silver and platinum, can mean only that no effective adsorption of the lubricant molecules on the titanium surface has taken place. Under these circumstances, the lubricant molecules get out of the way whenever the titanium asperities come into contact, and hence are unable to reduce friction or surface damage. This behavior is attributable to the titanium oxide layers

Table II – Coefficient of Friction for Lubricated Surfaces

Lubricant*	Coefficient of Friction (f)	
	Ti on Ti	Steel on Steel
Liquid		
None	0.47	0.53
Cetane	0.46	0.25
Palmitic acid in cetane	0.47	0.11
Ucon fluid LB 285	0.46	0.15
Silicone Dow 200	0.45	0.42
Solid		
Cetylamine	0.38	0.08
Palmitic acid	0.18	0.08
Copper palmitate	0.14	0.10
Graphite	0.15	0.11
Molybdenum disulphide	0.14	0.08

*Single passage over track at a velocity of 0.1 cm. per sec. and 1000-g. load.

rather than to the titanium itself, which, being a fairly electronegative metal, would be expected to adsorb such substances as palmitic acid in cetane.

Solid lubricants are able to reduce the friction, since the lubricant molecules, owing to their limited mobility, remain between the sliding titanium surfaces. But the very small absorption of the lubricant shows itself in the ease with which the lubricant is removed by repeated sliding along the same track. Table III gives some typical data on the number of revolutions required for the coefficient of friction to reach 0.25, this being arbitrarily taken as the point at which the lubricant had been worn away to such an extent as no longer to be effective. The contrast between the good lubrication on the steel and the poor lubrication on the titanium is very evident.

Under these circumstances the most effective lubricants are those that, in addition to having a low shear strength and thus low friction, are firmly supported laterally. Some of the new resin-graphite and resin-molybdenum disulphide combinations have shown distinct promise. Figure 3 shows typical results obtained through the use of one of these resins, namely "DAG 213" (graphite in Epon resin) and its effective lubricating ability is evident.

Table III – Wearing Qualities of Some Solid Lubricants

Lubricant	No. of Runs Before f Reaches 0.25	
	Ti on Ti	Steel on Steel
None	0	0
Cetylamine	0	800
Palmitic acid	2	>1000
Copper palmitate	4	>1000
Graphite	12	>1000
Molybdenum disulphide	12	>1000

FRICTIONAL PROPERTIES OF TITANIUM ALLOYS AND OF ZIRCONIUM

Examination was made of a number of commercial titanium alloys, namely, Ti-75 A and 150 A, RC-55, 70, 130 A and 130 B, and RS-55, 70, 110 and 120. Sliding tests of these alloys on themselves showed that the welding and nonlubricating action was essentially the same for all, with somewhat better sliding conditions with the harder alloys containing hard metals such as chromium and manganese. The addition of soft metals, such as lead, might be preferable from a frictional aspect.

The metal zirconium, too, showed very similar friction properties, and its welding behavior was only slightly less marked than that shown by titanium.

Discussion – Two main results emerge from these experiments. The use of clean surfaces showed that titanium easily forms strong welds with other metals, and in consequence large amounts of titanium fragments are transferred to the other metal.

The other result relates to the behavior of lubricants on titanium. It seems that even those lubricants which are effectively adsorbed on other metals are only weakly adsorbed on titanium, and hence are not able to protect the titanium during sliding. Solid lubricants are able to afford such protection but they are weakly bonded to the surface and are easily pushed aside during sliding.

A number of interesting conclusions follow from the investigation. The coefficient of friction for clean titanium (0.5) is little affected by accidental contamination, and thus titanium may be useful for applications in which high, constant friction coefficients are required.

The important effect of geometry on the frictional properties of titanium-other-metal combinations has been demonstrated. In sliding experiments in which one of the surfaces is of titanium, it should be the surface of smaller sliding area; for example, the piston of a piston-cylinder combination. A technique for diminishing the importance of the titanium fragments is to make the other metal soft (its Vickers hardness should be less than about 1/6th that of the titanium) so that the titanium fragments sink in and become buried.

Although liquid lubricants are in general completely ineffective, some limited success has recently been achieved using some of the Ucon fluids of high viscosity (such as LB 1800 X which gives a coefficient of friction of 0.32).

When a solid lubricant film is acceptable, perhaps the best lubricating treatment consists of one of the plastic-molybdenum disulphide or one of the plastic-graphite combinations. It appears that the development of correspondingly good liquid lubricants will require chemical modification of the titanium surface oxide layers. In view of the inert nature of these layers, it will be difficult to design a lubricant that will react with the surface film and yet can be used in ordinary applications.

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company, Division of Union Carbide Canada Limited, Welland, Ontario

COLUMBIUM and TANTALUM

Strategic Combination for Imparting Strength and Stability to High-Temperature Metals

Gas turbines for jet aircraft engines, and for other similar engines being developed for marine and railway transportation, have greatly increased the demand for high-temperature metals. The present most satisfactory metals are either iron-base, nickel-base, or cobalt-base. They are used in the form of castings and hot-worked products, such as forgings, bars, and sheets.

Many of these special metals contain columbium because of its beneficial effect on high-temperature strength in both cast and wrought products. Investigations have shown that columbium is one of the key alloys for imparting high-temperature strength and stability in metals suitable for operating temperatures up to 1500 deg. F. and above.

Need for New Alloy

Originally, a ferrocolumbium alloy containing approximately 55 per cent columbium and 5 per cent tantalum was employed in the production of many of these high-temperature metals. However, with the increased use of high-temperature metals and columbium-bearing 18-8 stainless steels, the demand for columbium exceeded its availability.

ELECTROMET's Research Laboratories began investigations to ascertain whether an alloy containing more tantalum and less columbium would be equally satisfactory for producing the high-temperature metals. Columbium and tantalum alone, as well as combination alloys of columbium plus tantalum, were tested.

Results of Tests

The alloy N-155 was selected for tests. It is an iron-base alloy with the following approximate analysis:

Chromium	20 per cent
Nickel	20 per cent
Cobalt	20 per cent
Tungsten	3 per cent
Molybdenum	2 per cent
Columbium	1 per cent
Nitrogen	0.15 per cent
Carbon	max. 0.35 per cent

The data in the table below describe the mechanical properties, at room temperature, of this low-carbon N-155 alloy modified with columbium and tantalum alone, and with combinations of columbium plus tantalum. The metal modified with columbium has good strength and high ductility at room temperature. These same good properties are obtained when tantalum, or tantalum plus columbium, is substituted for the columbium.

Stress-to-rupture tests were also conducted on these same modified low-carbon N-155 alloys at 1350 and 1500 deg. F. The data show (see table) that when the columbium is replaced with a mixture of columbium plus tantalum, the strength of the metal remains substantially unaffected at 1350 and 1500 deg. F. Also, when all of the columbium is replaced with tantalum, the strength of the metal at 1500 deg. F. is equivalent to that obtained with columbium. Hence, from the standpoint of high-temperature strength, columbium and tantalum can be used interchangeably, or in combination.

Properties of Modified N-155 Alloys Compared*

Typical Analysis, %**	With Columbium	With Columbium and Tantalum		With Tantalum
Columbium	1.13	0.58	0.49	....
Tantalum	0.08	0.64	0.53	1.47
Carbon	0.12	0.13	0.13	0.12
Nitrogen	0.13	0.14	0.14	0.14
At Room Temperature				
Tensile Strength, psi	119,000	123,200	117,500	122,100
Yield Strength, psi	56,700	59,500	52,000	59,100
Elongation in 2 in., %	52	47	57	54
Reduction of Area, %	69	65	69	56
At 1350 deg. F.				
Stress to Cause Rupture, psi				
In 100 hr.	31,000	34,000	33,500	....
In 1000 hr.	23,000	25,000	23,000	....
At 1500 deg. F.				
Stress to Cause Rupture, psi				
In 100 hr.	20,000	20,000	20,500	20,000
In 1000 hr.	15,000	14,000	15,500	15,000

* Tests made on standard samples from one-inch round bars, water-quenched from 2250 deg. Fahrenheit.
** Composition of the base alloy is given in the text.

Help to Industry

ELECTROMET has developed an alloy containing approximately 20 per cent tantalum and 40 per cent columbium for use in high-temperature metals and stainless steels. It is known as ELECTROMET ferrotantalum-columbium.

Industrial experience with this comparatively new alloy has confirmed the favorable results of the experimental work. The alloy has already aided considerably in augmenting the supply of columbium alloys, since it is just as effective as ELECTROMET ferrocolumbium, with 50 to 60 per cent columbium, for giving strength at high temperatures.

Furthermore, the new alloy is now preferred because of its greater availability. It should be added to a thoroughly deoxidized metal bath to obtain the best results. A recovery of about 90 per cent for the columbium and 80 per cent for the tantalum may be expected.

For further information regarding alloys for high-temperature metals, write to the nearest ELECTROMET office: in Birmingham, Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, Pittsburgh, or San Francisco. In Canada: Welland, Ontario.

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Correspondence

Credit Where It Is Due

NILES, OHIO

In the article "Metallographic Structures in Commercial Titanium" which appeared on p. 93 of the November issue of *Metal Progress*, credit was incorrectly given to the P. R. Mallory Co. for the development of an electrolytic etching procedure. This work was done by Harold Margolin and Elmars Ence of New York University. The error was not yours nor that of Metcut Research Associates, but occurred through a general misunderstanding. I would appreciate your efforts in correctly ascribing this work to New York University.

LEE S. BUSCH
Director of Research
Mallory-Sharon Titanium Corp.

Chromium Diffusion Into Steel

LONDON, ENGLAND

Many improvements have recently been made in the method of diffusing chromium into the surface of steel and cast iron. The chromium-containing compound is now sprayed or applied by rollers in layers 0.010 to 0.020 in. thick, allowing for close packing of flat sheets or blanks. The usual temperature for processing close-packed sheets of 22 gage and over is from 1800 to 1870° F., the time at temperature being from 8 to 12 hr. Thicker gages require slightly higher temperatures (1870 to 1900° F.) and the same period at temperature. For cast iron, however, temperatures as low as 1300 to 1380° F. can be used for chromium diffusion, thus minimizing danger of distortion.

A special composition of pack compound has been developed which produces on low-carbon steels a bright finish similar to that obtained by conventional electropolishing. Processing temperatures with this compound have to be not less than 1920° F.

Some of the new applications for chromium diffusion which have been perfected or are being investigated include the following:

Fuel pumps and cast iron bodies have been treated by Diffusion Alloys, Ltd., for resistance to wear and corrosion. Large kitchen sinks are being fabricated from chromium-diffused sheets; these are stainless welded.

Greatly improved performances have been achieved on chromium-diffused cast iron molds and dies for the glass industry. This may prove to be of considerable importance in the glass manufacturing field. Furthermore, chromizing has given most effective bonding for vitreous and refractory enamels on steels, comparable to that obtained with Nimonic 75.

Nickel alloy parts for aircraft spark plugs are now chromium-diffused and give excellent performance in service.

T. BISHOP

Claims Statement on Zr Alloys Is Contrary to General Rule

MELBOURNE, AUSTRALIA

E. T. Hayes and W. W. Stephens stated in *Metal Progress* for May 1953 ("The Metallurgy of Zirconium", p. 97) that, since certain alloying elements have low solid solubility in alpha zirconium, it is improbable that the alloys will show any great strength. This view seems to be contrary to a somewhat generally accepted rule that the lower the solid solubility of an element in an alpha phase, the greater will be the strengthening effect per unit weight addition of that element. This appears to hold for interstitial and substitutional atoms.

G. V. Smith[1] has reviewed the great amount of work which has been carried out to determine the strengthening effects of solute atoms in lead, copper, silver and iron. Recent work by J. E. Dorn[2] on aluminum, a letter by M. A. Meyer[3] discussing nickel, and the work of W. L. Bruckart[4] with molybdenum are also relevant. These studies indicate the existence of this general rule and similar relationships with such features as the degree of lattice distortion and the difference in ionic size of solute and solvent.

It may be argued that even though this rule applies, elements having low solid solubility will not produce appreciable strengthening because of the difficulty of introducing sufficient amounts into the solution. This is not so, however. Considering copper-base alloys[1], tin strengthens more than do large amounts of manganese or nickel — even though tin is least soluble, manganese slightly more soluble and nickel completely so. With iron-base alloys[1], copper is only soluble to approximately 1.5% and an alloy containing 1% copper is much stronger than one containing 5% cobalt. Cobalt is widely soluble in alpha iron.

(Continued on p. 114)

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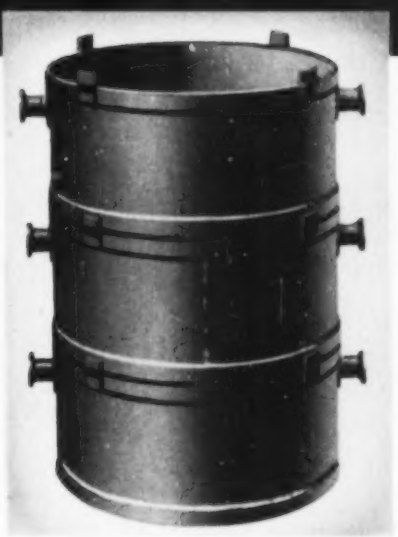
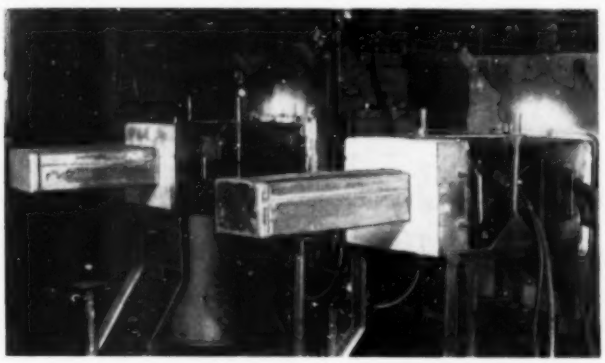
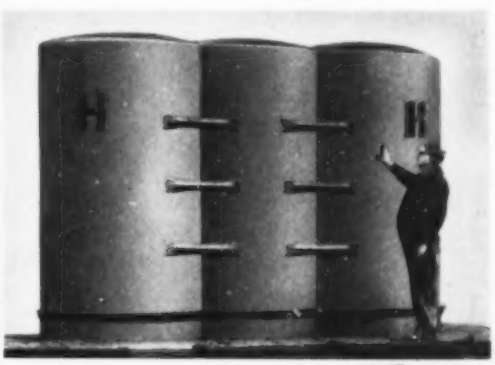


Retort for small lots of different parts -- one of many special-purpose PSC heat-treat units.



Above, retorts for 2150°F. At right, light-weight hoods; handle easily. PSC fabricates complete list of ferrous and non-ferrous metals, alloys.



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Correspondence

(Continued from p. 112)

An exception to this rule is reported[5] for alpha titanium alloys. Of the interstitial elements carbon, oxygen and nitrogen, the element with the lowest solubility in alpha titanium, namely carbon, has the least hardening influence. Also, oxygen and nitrogen, which are the most potent hardening elements, have much less influence on the lattice parameters and C/a ratio than does carbon.

If low strengthening is shown by alpha zirconium alloys as Messrs. Hayes and Stephens state, this may be another indication that the rule is invalid when applied generally.

References

1. "Strain-Hardening-Effects of Alloying Elements and Microstructure", by G. V. Smith, from "Cold Working of Metals", American Society for Metals, Cleveland, 1949.
2. "The Effect of Alloying Elements on the Plastic Properties of Aluminum Alloys", by J. E. Dorn, P. Pietrokowsky and T. E. Tietz, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 188, 1950, p. 933-943.
3. M. A. Meyer, *Bulletin* of the Institute of Metals, Vol. 14, 1952, p. 121.
4. "Recrystallization of Wrought Hydrogen-Sintered Molybdenum and Its Alloys", by M. H. LaChance, W. L. Bruckart, C. M. Craighead, and R. I. Jaffee, *Transactions* of the American Society for Metals, Vol. 45, 1953, p. 314-332.
5. "Effects of Three Interstitial Solutes (Oxygen, Nitrogen and Carbon) on the Mechanical Properties of High-Purity Alpha Titanium", by W. L. Finlay and J. A. Snyder, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 188, 1950, p. 277.

S. T. Quaass
Aeronautical Research Laboratories
Dept. of Supply

Statement on Zr Alloys not Meant to Be Revolutionary

Albany, Ore.

We had no intention in our article to repeal the fundamental laws of metallurgy; the statement that was made was only a generalization and did not differentiate between the effect of various elements on the properties of alpha zirconium.

Although precise work has not been done on the solubility of such elements as iron, nickel, chromium, copper and molybdenum in alpha zirconium, it has been fairly well established that the maximum solubility is in the range 0.1 to 0.2% by weight. Certainly, the strengthening effect of these quantities will be quite small. Although the problems of preparing zirconium alloys in this range are legion, they are not impossible and could be accomplished if one had considerable backing for such fundamental studies.

It is recognized that with the addition of chromium, for instance, additions of less than 0.1% may seriously affect or destroy the ductility of the metal. Since no such profound changes occur in zirconium, and since the expected changes in strength values would be nearly within the limits of testing error, it is difficult to see what would be gained from a practical viewpoint.

The warranted assumption that low alpha solubility results in greater strengthening effect will probably have to await actual proof for several years for the above-mentioned zirconium systems.

Earl T. Hayes, Chief
Physical Metallurgy Branch
U.S. Bureau of Mines

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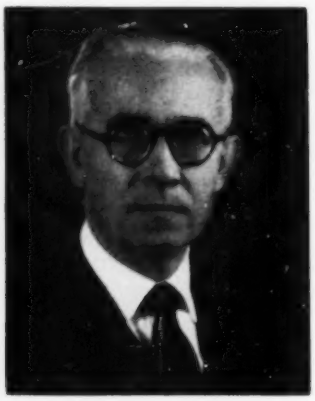
Personal Mention

James P. Gill



Antonio Scortecci

JAMES PRESLEY GILL, past national president, has been elected president of Vanadium-Alloys Steel Co., Latrobe, Pa. Mr. Gill joined the company in 1920 as chief metallurgist, and in 1943 was elected vice-president. In 1945 he was made chairman of the Executive Committee of Vanadium-Alloys Steel Co. and its subsidiaries, and is now president of the Colonial Steel Division and of Vanadium-Alloys Steel, Canada, Ltd. Mr. Gill has been an active member of the American Society for Metals since its founding. He was a charter member of the Pittsburgh Chapter, and was its chairman in 1926-27. He was chairman of the Handbook Committee in 1939, served as a trustee in 1937, and was elected national president in 1939. Jointly with Lloyd D. Bowman, he received the Silver Medal in 1922, the only silver medal ever awarded, for the following year the Henry Howe Medal was instituted to take its place. Born in Montgomery City, Mo., Mr. Gill received his education at the University of Missouri School of Mines and Metallurgy and at Columbia University. Mr. Gill is the principal author of "Tool Steels," the best-selling textbook now in its fourth printing, and is a much sought-after speaker and lecturer for various technical groups and societies.

In a memorable ceremony on April 28, 1953, ANTONIO SCORTECCI, director of Istituto Siderurgico "Finsider" (holding company for Italian steelworks) and professor of metallurgy at University of Genoa, was presented with the cross of the French Legion of Honor for his scientific accomplishments, particularly in metallurgy. This award, the highest bestowed by the French Government (and seldom on anyone other than a Frenchman), was made by the French Ambassador to Italy before an audience consisting of the president and deans of the various departments at the University of Genoa, directors of "Finsider", and civic leaders.

Professor Scortecci was born in Florence and graduated in chemistry from the University of Florence in 1919. His career since then has combined teaching, research and industrial executive positions in about equal proportions, including association with such firms as E. Breda (munitions), Ansaldo Steelworks, Ilssa and Ilva Steelworks. He has been director of the Finsider Institute since 1948, where he promotes such activities as the selection and professional training of university graduates, instigation of research projects, and development of a complete bibliographic service (a part of which is based on the ASM-SLA classification of metallurgical literature, which he actively promotes). Professor Scortecci is vice-president of the Italian Association of Metallurgy, an honorary member of the French Society of Metallurgy, and active in numerous other technical societies in various countries. He has been the Italian delegate to many important international committees having to do with European steelmaking, and of several OEEC-sponsored study groups in this country, including the World Metallurgical Congress in 1951.

Carl A. Julien has resigned as assistant executive secretary of the Minerals and Metals Advisory Board, National Research Council, Washington, D.C. and joined the Washington office of General Electric Co. as an attorney.

Alan Harrison, fellow of the Institute of Metallurgists and associate of Sheffield University, England, is now vice-president and chief metallurgist of Hayward Tyler of Canada, Ltd., Waterloo, Ont. Prior to this assignment, Mr. Harrison was foundry works manager of Firth Vickers Stainless Steels, Sheffield, England.

Frederick R. Bullivant, a graduate of the Missouri School of Mines and Metallurgy, is now employed as sales engineer in the industrial heating division of Westinghouse Electric Corp., Meadville, Pa.

Burt Reese has been transferred from the metallurgical department, Sanderson-Halcomb Works, Crucible Steel Co. of America, Syracuse, N.Y., to the Boston sales office and is now working out of that branch as a sales-service engineer.

George A. Tracy, a June 1953 graduate of Iowa State College with a M.Sc. degree in metallurgy, is now employed as a metallurgist and engaged in alloy development work at Wright Aeronautical Div. of Curtiss-Wright Corp., Wood-Ridge, N. J.

Jerome Lee Hoffman, formerly with Caterpillar Tractor Co., Peoria, Ill., is now employed by the Alabama By-Product Corp., Birmingham, as a foundry service engineer on melting practices.

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Personals

David K. Priest received a Ph.D. degree from Ohio State University in August 1953, and is presently employed as a research engineer on glass and metals corrosion with Pfaudler Co., Rochester, N. Y.

Paul J. Aicher has been appointed district manager of the Chicago area for the Beryllium Corp., Reading, Pa.

George J. Barth, upon graduating from Carnegie Institute of Technology with a B.S. degree in metallurgical engineering, accepted employment with the Westinghouse Electric Corp., Pittsburgh, and is now taking part in the graduate student program.

Paul E. Hegmegee, Jr. is now employed as metallurgist with the technical section of the Bayonne (N. J.) Works of the International Nickel Co.

Stanley Rothschild, after completing the two-year training course at Allis-Chalmers Mfg. Co., Milwaukee, has accepted a graduate assistantship in the mineral preparation division, School of Mineral Industries, Pennsylvania State College.

John F. Puterbaugh, who is employed by Remington Arms Co., Inc. at the Lake City Arsenal, Independence, Mo., was recently promoted to the position of associate engineer. His responsibilities include supervisorship of the metallurgical and physical testing laboratories.

F. P. Whalen has been promoted from division metallurgist for the American Steel & Wire Co., Worcester, Mass., to metallurgical engineer and has been transferred to Cleveland.

J. O. Huffman has been made supervisor of engineers and is working on fabrication processes for guided missiles in the materials and processes department of North American Aviation, Inc., Inglewood, Calif.

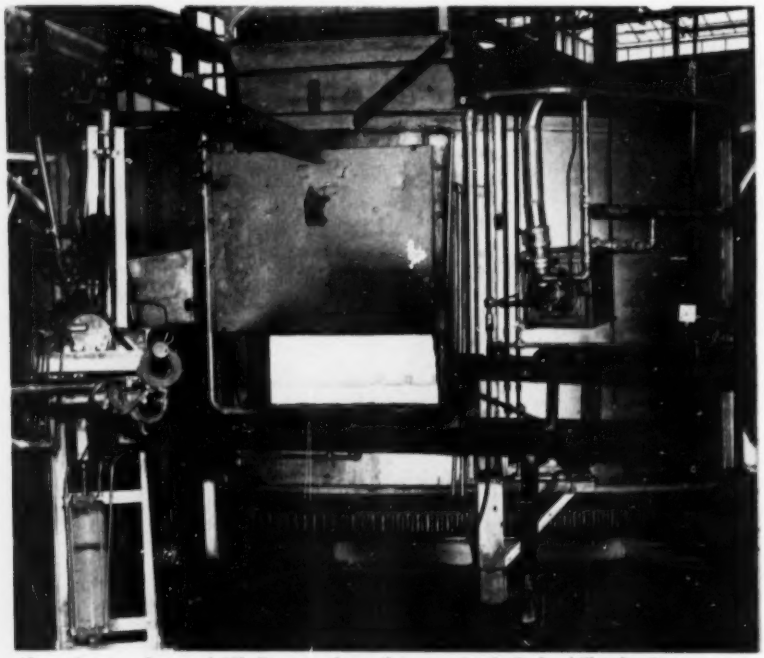
Edward Dillingham is now a member of the Hughes Cooperative Plan, studying for the degree of master of science at the University of Southern California and working on the development of guided missiles at the Hughes Aircraft Co., Culver City, Calif.

H. C. Dameron, Jr. has been transferred from the Lafayette (Ind.) Works of the Aluminum Co. of America to their Rockdale, Texas, plant, where he is serving as metallurgist in the metal services department.

Matts G. Snellman, who received the M.S. degree from the University of Pittsburgh in 1951 and a Ph.D. from the same school in 1953, is now melt shop superintendent at the Imatra Steelworks in Imatrankoski, Finland.

W. L. Argus, formerly vice-president in charge of operations at Dixie Corp., Rome, Ga., has resigned that position to accept the post of vice-president in charge of national sales of Weather Products, Inc., Hialeah, Fla.

Vincent Frick has accepted a position with the Ryan Aeronautical Co., San Diego, Calif., in the engineering welding development laboratory.



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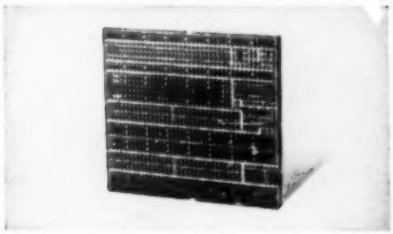
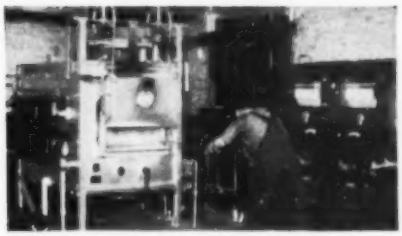
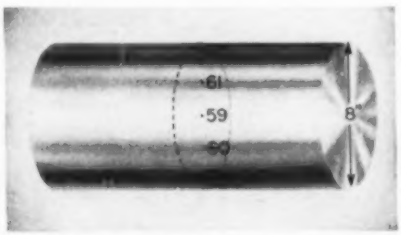


Freedom from Size Change in Hardening. The mold for this 9½" x 10½" plastic control panel has 1,280 $\frac{5}{32}$" dia. holes, six $\frac{3}{8}$" dia. horizontal ports for heating and cooling, plus eight ¾" dia. tapered holes on the edge. *Vega* was the *only* steel of many tried that could successfully hold the close tolerances of .0002" on centers of the 1,280 holes! Will the steel you use behave in hardening like this?



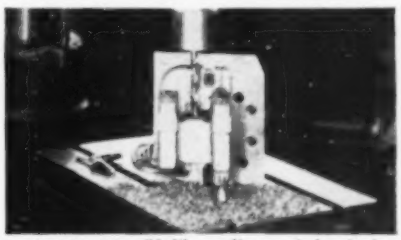
Easy, Low Temperature Heat Treating. You heat treat *Vega* from a temperature of only 1550°F (actually 200°F *lower* than the 5% chromium air-hardening grades!). No need for special, high temperature furnaces! Are you getting the benefits of *low temperature* heat treating from the air-hardening steel you use?

Extra Economy in Hardening. Because of *Vega's* lower hardening temperature, troublesome pack hardening to avoid excessive scaling is usually unnecessary. Does the air-hardening steel you use give you this *extra economy* in hardening?



Uniform Deep Hardenability. *Vega* gives you the advantages of uniform, deep hardenability in very heavy sections. For example, *Vega* hardens to Rockwell C-60 from surface to center in sections as large as 8" round. How does the steel you use compare on this score?

Toughness with Good Hardness. This punch and die blanks ¼" diamond threshold plates at one stroke. With previous air-hardening die steel, tools chipped and broke before any real production was made. With *Vega* these tools are in regular production—and there are no signs of wear or chipping to date. Will the steel you use perform in service like this?



Good Machinability. Unlike ordinary air-hardening grades, *Vega* has a well balanced analysis with a small percentage of hard-to-machine alloys. Field tests prove it to be one of the easiest of all air-hardening grades to machine. If the air-hardening grade you use fails to provide this *good machinability*, you're missing out on lower costs.

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Export Department: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO"

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Personals

David Spear is vice-president of the newly organized subsidiary of the Maremont Mfg. Corp. in San Juan, Puerto Rico.

Alfred C. Harris has been transferred to the Detroit office of the Cincinnati Milling and Grinding Machine Co. as sales specialist in their Flamatic Division.

T. G. Thurston is now the Cleveland district representative for the Selas Corp. of America, with a territory covering northeastern Ohio.

Wm. P. McKinnell, Jr. has been released from the U. S. Navy and has resumed graduate study at the Ohio State University. Before he was recalled to active duty, Lt. McKinnell was assistant professor in the department of metallurgy at Virginia Polytechnic Institute, Blacksburg, Va.

Dino Ravasio has accepted a position with the U. S. Steel Corp. in the Duquesne (Pa.) Works. Mr. Ravasio is currently in the metallurgical development department, working as a management candidate trainee.

Edward Lipski is now employed at the Midland (Pa.) Works of Crucible Steel Co. of America as claim investigator in the metallurgy laboratory.

Donald E. Dorney, who graduated from Lehigh University with a B.S. degree in metallurgical engineering in June 1953, is now employed by E. I. du Pont de Nemours & Co., Inc., in Belle, W. Va., as metallurgist.

Richard T. Brewer has recently been transferred by the engineering department of E. I. du Pont de Nemours & Co., Inc., from the Wilmington, Del. office to their Savannah River plant.

Kenneth A. Lambert, Jr. has accepted a position as metallurgist, Montrose Division of Bendix Aviation Corp. in South Montrose, Pa.

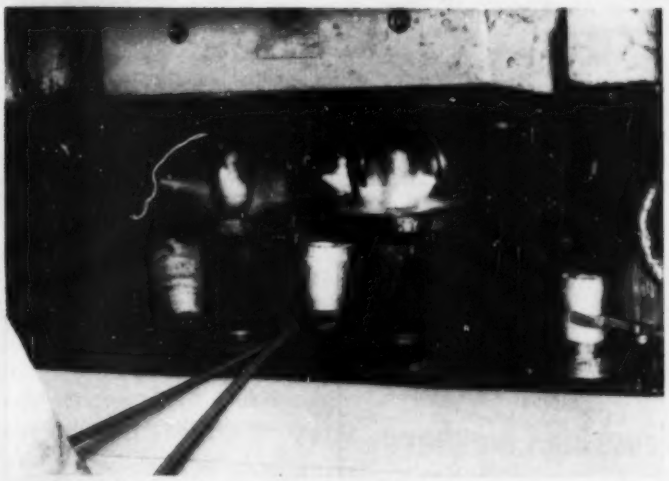
Pat A. Santoli is now project engineer in the high-temperature alloy section, metals branch of the materials laboratory, at Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio. Lt. Santoli's duties are concerned with precision foundry methods and their development, service engineering, and the monitoring of research contracts for the development of heat resistant, cast iron-base alloys.

Jerome Baird has accepted a position as associate metallurgist with Argonne National Laboratory at Lemont, Ill.

E. L. Kemper has accepted a position as field engineer for the A. F. Holden Co., representing the company in Minnesota and Wisconsin.

Joseph J. Phillips, for ten years on the staff of Battelle Memorial Institute at Columbus, Ohio, first as research technician, then as an administrative assistant and in the final year as technical editor, is now employed by the Haynes Stellite Co., Kokomo, Ind., as technical editor and as head of the data, editorial and publication unit of the research department.

500 81-MM Shell Blanks Per Hour on a 1,600-Ton High Speed Forging Maxipres!



Upset slugs, heated to 2100°F., are cupped by extrusion, then shaped in forming die. High-pressure jets of mixed air and water keep punches and dies cooled to about 550°F.

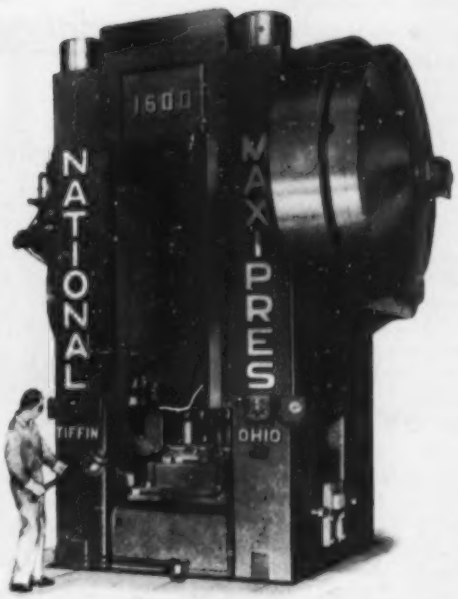
Slugs for 81-MM mortar shells are sheared from 2½ inch round bars of carbon steel. Slugs are then upset preparatory to extrusion (center illustration).

Upset slugs are extruded, then formed into cups (right).

● An outstanding production record is being established at Rheem Mfg. Co., progressive West Coast ordnance forgers, where 81-MM mortar shell blanks are being forged on a 1,600-ton National MAXIPRES at the rate of 500 blanks per hour!

Dies, developed in cooperation with NATIONAL engineers, are giving exceptionally long service. The punches have produced 14,000 to 16,000 pieces, average. After forming 15,000 cups, one die was polished, and produced another 63,000 pieces before showing much wear!

If you have a forging problem—large or small, hot or cold, ferrous or non-ferrous—let us help you solve it. Send us prints, or a sample part, or, better yet, visit us. No obligation.



MAXIPRESSES are available in 13 sizes from 300- to 8,000-ton.

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Hartford Detroit Chicago

Personals

John Guernsey, formerly a research technologist with the Lunkenheimer Co., Cincinnati, is now a staff metallurgist in the research group, for Rem-Cru Titanium, Inc., Midland, Pa.

James S. Kirkpatrick, for the past two years director of research and development for Brooks & Perkins, Inc., Detroit, has been elected vice-president, research and development. Mr. Kirkpatrick is a member of the Handbook Committee.

Arthur P. Wichmann has been appointed acting head of the department of metallurgy of the Colorado School of Mines. Professor Wichmann is a graduate of the University of Wyoming in mining engineering, and holds the degree of master of science in metallurgy from the University of Washington. He joined the staff of the Colorado School of Mines as assistant professor of metallurgy in 1937, and attained the rank of full professor in 1952. During World War II he served as chief of the Copper and Aluminum Sections of the Office of Civilian Supply in the War Production Board.

William John Brigham has been appointed district manager of the Cincinnati office of the steel and tube division of the Timken Roller Bearing Co. of Canton, Ohio. Mr. Brigham started with the company in 1940 as a metallurgist, and in 1944 became a sales engineer and was sent to Timken's Chicago office, where he remained until the present.

Philippe J. P. Dubois, who came to the United States from Germany on an exchange student program, spent six months in Madison, Wisc., and has recently moved to Chicago. Mr. Dubois is a graduate of Strasbourg University, and is employed by U. S. Steel Corp. as an observer.

W. D. Trueblood, Jr., of the Chicago sales office of Leeds & Northrup Co., Philadelphia, has been transferred and named manager of the company's newly opened Milwaukee office.

Sydney E. Gregory has been appointed sales representative for Alloy Precision Castings Co., Cleveland. Mr. Gregory, a graduate of the Kilburn Polytechnic University in London, England, came to the United States in 1948 after having served with the British Eighth Army, and was previously general manager of the permanent mold division of Barnes Mfg. Co., Mansfield, Ohio, and sales manager of Pressco Casting & Mfg. Corp., Chesterton, Ind.

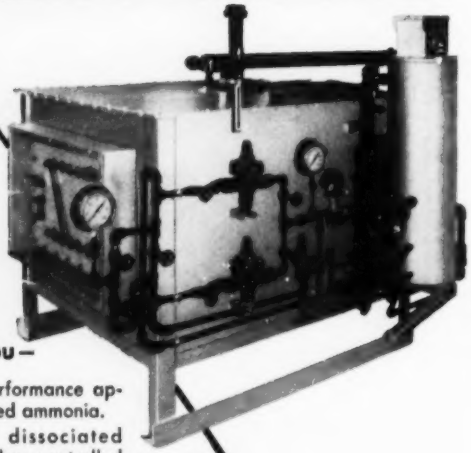
Hugo E. Johnson has been appointed vice-president of the Lake Superior Iron Ore Association. Mr. Johnson, a research engineer in the iron and steel industry since 1925, has been assistant manager of the project development group of Battelle Memorial Institute, Columbus, Ohio, for the last five years. Previously, he was associated with the Youngstown (Ohio) Sheet and Tube Co. and the United States Steel Corp. in research and engineering positions.

Philip R. Freeman, until recently sales manager of Coulter Steel & Forge Co., Emeryville, Calif., has been promoted to vice-president and treasurer of the company and as such also assumes the responsibility as general manager. Mr. Freeman, a graduate of Yale University, served in the U. S. Marine Corps in World War II and holds a reserve commission as lieutenant colonel.

S&W AMMONIA DISSOCIATORS

with HORIZONTAL Cracking Chambers

are unconditionally guaranteed



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Cost-saving, better performance applications for dissociated ammonia.

10 advantages of dissociated ammonia over all other controlled atmospheres you have used.

S&W ammonia dissociating process, with schematic flow diagram of installation we recommend for you.

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186 Weeden Street, Pawtucket, R. I.

Electric and Fuel-Fired Furnaces • Atmosphere Generators • Gas Conditioning Equipment

"We've reduced darkroom work 50%– saved up to 40 man-hours weekly– and minimized static problems WITH DU PONT 506 N. I. F.,"*

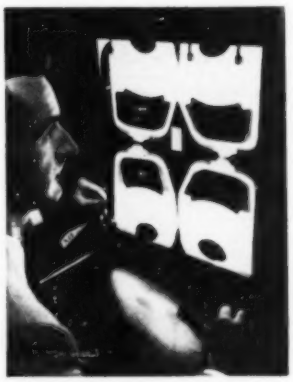
reports Alan S. Kollock, President, Industrial X-Ray, Inc., West Hempstead, N. Y.

One of the largest independent testing "labs" in the East, Industrial X-Ray, Inc., West Hempstead, N.Y., specializes in fast, dependable x-ray inspection service. An established user of Du Pont Film, the laboratory recently tried Type 506 N.I.F. The convenience in film-handling of the new package speeded up darkroom work, and it's now being used in scores of testing jobs for welding concerns, foundries, and manufacturers of automotive and aircraft parts.

In telling why the switch to N.I.F. was made, President Alan S. Kollock explained: "N.I.F. has several features that are important to us. The big point is the elimination of interleaving paper. Technicians work faster . . . avoid tedious paper-handling and disposal operations. Our tests show that N.I.F. reduces darkroom work 50% and saves up to 40 man-hours weekly.

Foreman Mario Grund positions tube before x-raying magnesium castings.

"We also find that N.I.F reduces static. Often, when we used films in interleaving paper, we had trouble with static. Now, that problem's solved. In checking our use of thousands of sheets of N.I.F., we've never found a static-marked film.



Mr. Kollock interpreting radiograph made on Du Pont Type 506 Non-Interleaved Film.

"We've always liked '506' because of its rugged base, its speed, and its wide latitude. Now that it's available in N.I.F. packages, there isn't another film that offers so much."

Today, Du Pont Type 506 Non-Interleaved Film offers industrial radiographers quicker, more efficient results. This newly developed film retains every benefit of regular Type 506 . . . dependable speed, fine grain and maximum contrast . . . and adds its own unique, "paperless" feature. So, to obtain clear, sharp, detailed radiographs—and simplify processing and handling—specify Type 506 N.I.F. next time you order. Packaged in space-saving 100-sheet boxes, it's available in all standard sizes. And for technical assistance with any type of x-ray inspection problem, contact the Du Pont representative in your area, or write: E. I. du Pont de Nemours & Co. (Inc.), Photo Products Department, Wilmington 98, Delaware. *In Canada: Canadian Industries, Ltd., Montreal.*

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*Non-Interleaved Film, made *only* by Du Pont.

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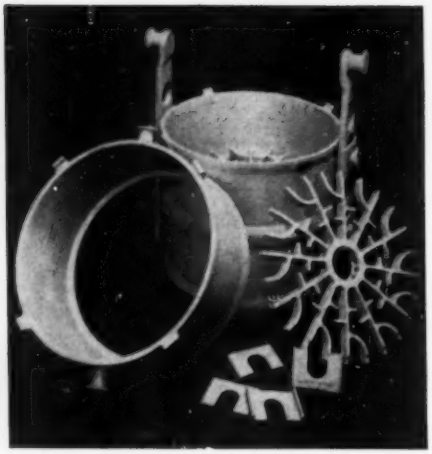
BETTER THINGS FOR BETTER LIVING
...THROUGH CHEMISTRY

MISCO
PIT TYPE FURNACE EQUIPMENT



NOMINAL FURNACE SIZE	DESCRIPTION	PATTERN NUMBER	WEIGHT LBS. EACH
20 x 24 and 20 x 36	Basket 19⅜" I.D. x 8¾" Deep	F-13021	72.0
	Basket 19⅜" I.D. x 13⅛" Deep	F-13020	95.0
	Grid 19⅛" O.D. x 1½" Deep	F-10016	21.0
25 x 24 and 25 x 36	Basket 24⅜" I.D. x 8¾" Deep	F-12904	85.0
	Basket 24⅜" I.D. x 13⅛" Deep	F-12903	122.0
	Grid 24⅛" O.D. x 1¾" Deep	F-9761	41.0
	Grid 24⅛" O.D. x 2" Deep	F-9582	45.0

ONE-PIECE CAST BASKETS AND GRIDS

LIFTING HOOKS AND LOCKS

NOMINAL FURNACE SIZE	DESCRIPTION	PATTERN NUMBER	WEIGHT LBS. EACH
20 x 24 and 20 x 36	Lifter for 3 Baskets 19⅜" x 8¾"	F-10013-A	15.0
	Lifter for 4 Baskets 19⅜" x 8¾"	F-10013-C	18.0
	Lifter for 3 Baskets 19⅜" x 13⅛"	F-12836-A	19.5
	Locks for the above	F-10013-B	1.2
25 x 24 and 25 x 36	Lifter for 3 Baskets 24⅜" x 8¾"	F-10014-C	27.0
	Lifter for 4 Baskets 24⅜" x 8¾"	F-10014-A	35.0
	Lifter for 5 Baskets 24⅜" x 8¾"	F-10014-D	41.0
	Lifter for 3 Baskets 24⅜" x 13⅛"	F-10934-A	35.0
	Locks for the above	F-10934-B F-10014-B	1.7 1.7

All items are designed for capacity loads at gas carburizing temperatures. Grids are replaceable. **ALL ITEMS ARE CARRIED IN STOCK IN MISCO METAL 37% NI—17% CR.** Also available in Misco K 25% Cr—20% Ni, and Misco B 25% Cr—12% Ni to special order.

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DIVISION OF EBALOY, INCORPORATED
One of the World's Pioneer Producers of Heat and Corrosion Resisting Alloys
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MISCO
Heat and Corrosion Resistant Alloys

Personals

Nathaniel C. Fick, director of the Metals and Minerals Panel in the Office of the Assistant Secretary of Defense for Research and Development, has been named chairman of the Speakers' Bureau for the District of Columbia Council of Engineering and Architectural Societies and the Washington Academy of Sciences.

T. W. Whiting is relinquishing his position as chief metallurgist for Guest, Keen & Nettlefolds, Ltd., Birmingham, England, to take up a post in Canada. Mr. Whiting has been appointed materials consultant to the Royal Canadian Navy at Ottawa.

N. H. Polakowski has resigned as I. C. I. Research Fellow in the metallurgical department of the University College of Swansea, England, to join the Armzen Co., of Waterbury, Conn.

Gilbert P. Muir has been appointed a sales representative covering western Pennsylvania for the Alloy Precision Castings Co., Cleveland, Ohio.

Charles E. Reardon has recently completed eight months' service as consultant to the Metallurgical and Conservation Branch of the National Production Authority in Washington, D. C., and has returned to his former post in industry as service metallurgist for the U.S. Steel Corp., Chicago.

John B. Barr, Jr. is now working as a metallurgist at the Park Works of Crucible Steel Co. of America, Pittsburgh.

Walter E. Foster, formerly mechanical design group leader in the radio and television division of Sylvania Electric Products, Inc., Buffalo, N. Y., is now project engineer in the appliance and electronic division of Avco Mfg. Corp., Cincinnati.

J. B. Meierdirks, Jr. has joined the materials and chemical processes department of the General Engineering Laboratory Division, General Electric Co., Schenectady, as a development engineer.

Vernon W. Eldred has recently received the Ph.D. degree at Cambridge University and has joined the staff of the Nelson Research Laboratories, English Electric Co., Ltd., Stafford, England.

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burners from 7000 to 15,000,000 B.t.u. per hour,
with 59 burner styles in 333 sizes

North American Mfg. Co. engineers complete combustion systems . . . you place all responsibility in *one* reliable organization.

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Incinerators • Ladle heating
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TURBO BLOWERS:
4 to 32 osi • 60 to 7560 cfm

VALVES:
Control • Limiting orifice • Manual shutoff • Safety shutoff

REGULATORS:
For gas, oil, and air

DUAL-FUEL LONG FLAME SEALED-IN BURNERS

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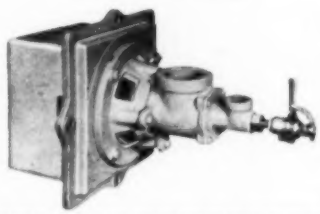
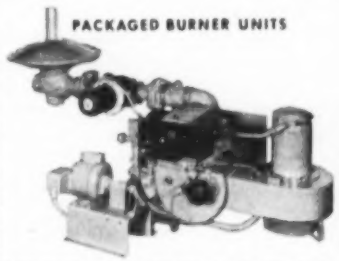
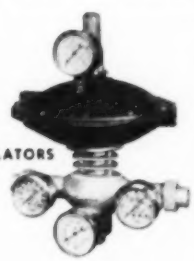


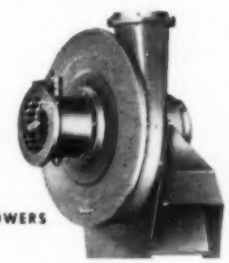
PACKAGED BURNER UNITS



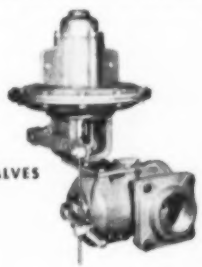
FUEL-AIR REGULATORS



TURBO BLOWERS



CONTROL VALVES



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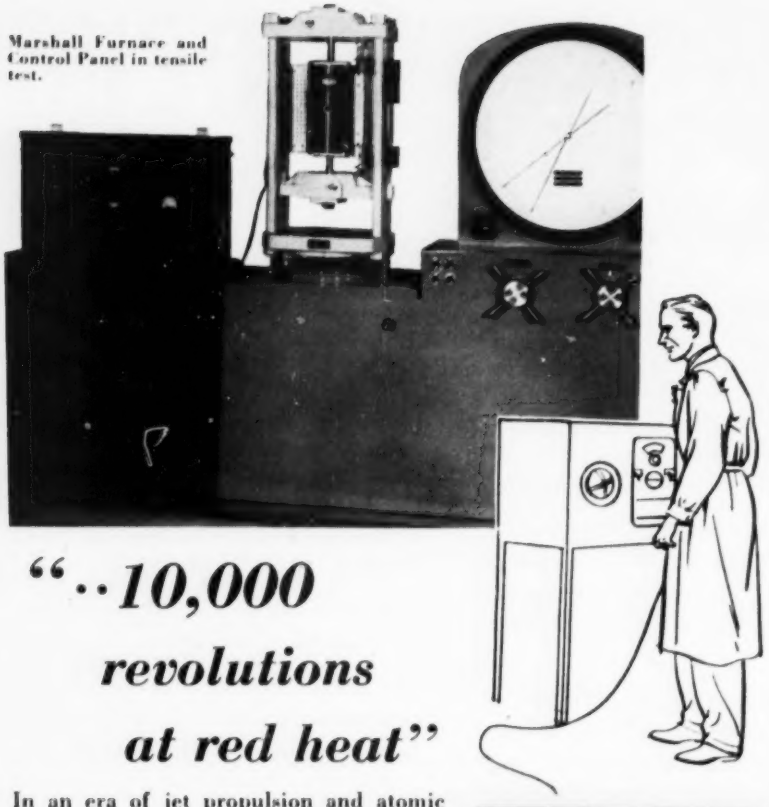


Marshall Furnace and Control Panel in tensile test.

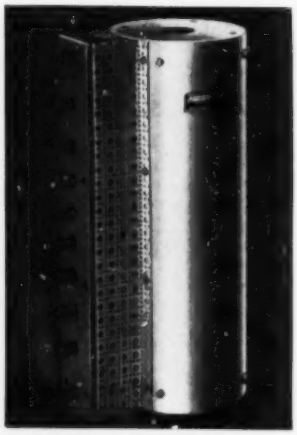
"..10,000 revolutions at red heat"

In an era of jet propulsion and atomic fission, ordinary tests of metal endurance are no longer adequate. Take for example, the metal alloys used in gas turbine rotor assemblies which whirl at 10,000 r.p.m. at red heat.

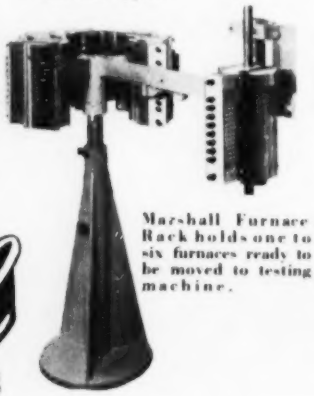
For such rigorous service, engineers must know their metals. The properties of their alloys when operating at these high stresses and temperatures must be predetermined. Engineers need to study tensile strengths, creep rates, time-to-rupture data.

Marshall Tubular Furnaces are built to yield this data. Engineers like the flexibility of heat-control this Furnace provides. Heat can be either uniform, spot-regulated, or zone-to-zone graduated. Behavior of the alloys under high temperature, stress, and fatigue are all revealed.

Maybe Marshall Furnaces are the testing units you need. *Write us regarding your requirements.* The Furnaces are already proven in atomic energy research, in testing valve steels, ceramets, jet engine and diesel parts, in metal refining, fabrication.



The above Marshall Furnace comes in Creep-Test and Tensile-Test Types.



Marshall Furnace Rack holds one to six furnaces ready to be moved to testing machine.

MARSHALL PRODUCTS CO
270 W. Lane Ave., Columbus 2, Ohio

Marshall

FURNACES--CONTROL PANELS

Sound Castings By Controlling Heat Transfer*

The Parlanti process is used to produce castings of very high physical properties and fills the gap between castings and forgings. Another benefit realized with the process is that skilled labor is not required to produce consistently high-quality castings.

According to the author, the essential components for the production of sound castings using controlled rates of heat transfer are:

1. Engineer, designer and metallurgist must work very closely together in the early designing stage.
2. Prototyping and development of "first offs" must be controlled by the laboratory.
3. Laboratory and production must have a very close liaison in the production stages.
4. The metallurgist must always be trying to lessen the variable conditions existing in the foundry.

Since it is accepted that castings produced in metal molds have stronger physical properties than castings produced in sand molds, it follows that a metal mold having known controllable rates of heat transfer should be preferable to a mold whose unknown heat transfer rates are irregular.

From a series of cooling curves (1060 to 210° F.) of various alloys and metals, a modification of aluminum alloy B.S. L33 anodized in an electrolyte of sulphuric acid solution was selected for use. Two years time was required to calibrate and balance the heat transfer rate from the mold interface to mold ambient conditions for various rates of filling the mold cavity. In contrast with the uncontrolled rate of heat transfer of cast iron molds the aluminum mold was so constructed that it functioned as "a heat transfer valve" which served to increase or decrease, at will, the heat transfer rate and thereby control the solidification of the molten material.

(Continued on p. 128)

*Digest of "The Production of Sound Castings by Controlled Rate of Heat Tranfer", by C. A. Parlanti, *Transactions* of the Institution of Engineers and Shipbuilders in Scotland, Vol. 96, Part 5, 1952-1953, p. 246-259.

Cowles AA (ACID ADDITION) COMPOUND

Stops Pickling Fumes

Cowles AA Compound is packed in fibre drums, 100 lbs. net and 250 lbs. net. AA is available for immediate shipment from conveniently located warehouses. Cowles Technical Service gladly furnished upon request.

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Cowles AA Compound produces a long lasting "FOAM BLANKET" that STOPS pickling fumes.

Cowles AA (Acid Addition) Compound literally "keeps the pickle in the tank", protects men and equipment from dangerous, damaging effects of acid fumes given off by pickle baths.

SPEEDS OPERATION

Cowles AA Compound controls acid fumes by *smothering* them. A *foam blanket* formed on the solution's surface keeps the fumes in the tank—where they belong! Acid strength is not reduced—AA actually *increases* pickling speed.

KEEPS BATHS CLEAN, RINSES FREELY

Cowles AA Compound keeps acid baths cleaner, speeds up soil breakdown, rinses freely and completely. AA can be added to any acids used in the metal pickling process.*

HELPS CONTROL TEMPERATURE

AA's *foam blanket* holds the heat in the tank, makes temperature control easier. Less steam is needed to reach and maintain workable temperatures. Just three ounces of AA to one hundred gallons of solution is the quantity usually needed.

STABLE, LONG-LASTING

Cowles AA Compound is a white, granular powder, dust-free and slightly acid. Added directly to the pickle bath, AA produces a stable, long-lasting *foam blanket.*

MAKES PICKLE ROOM "LIVABLE"

The *foam blanket* will stop the unpleasant, destructive fumes; will make your pickle room a pleasanter place to work in; will lengthen the life of your equipment; will save time and money in the pickling operation.

*When non-oxidizing acids are used consult your Cowles Technical Man.

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Sound Castings by Controlling Heat Transfer

(Continued from p. 126)

The ingate is located at the thickest metal section. Proper flowing of the liquid metal requires that the mold temperature should momentarily rise toward that of the liquid and then rapidly decrease. Good structure and casting detail result from rapid solidification and proper positioning of risers. The Parlanti process requires risers of greater feeding capacity than other casting methods.

The advantages claimed for the anodized mold surface are as follows:

1. The Al_2O_3 surface has a high melting point – in excess of 3600° F.
2. The refractory surface prevents fusion between the molten material and the mold.
3. Time is provided so that the mold will not become saturated with too high a temperature level.
4. The surface is very hard and resists erosion, resulting in prolonged mold life.
5. Molds can be readily manufactured.

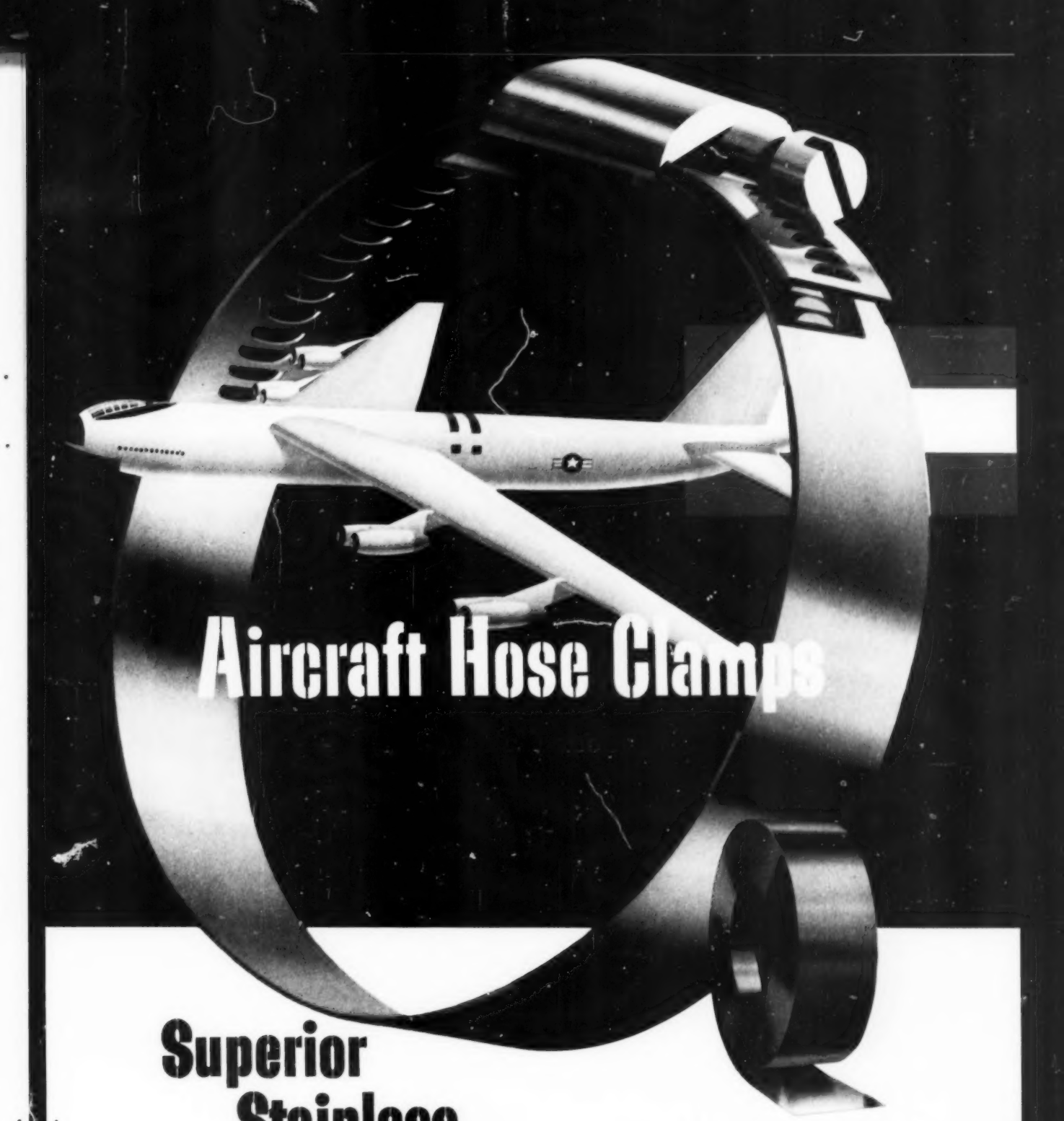
The slower rate of heat transfer of cast iron and steel, combined with the high rate of heat transfer of the anodized mold, permits the pouring of those alloys in such molds. Die-cast aluminum cores can be used and melted out at the appropriate time by transferring to the core the required amount of heat. Acceleration of core melting can be accomplished by using a hollow core, by not anodizing certain parts or by providing external finning.

The following examples are given of castings produced by the Parlanti process:

1. A 450-lb. as-cast ring, 5 ft. in diameter, from Alloy L33.
2. A segmental mold for a radar paraboloid which in the as-cast condition weighed 600 lb.
3. An elbow from alloy D.T.D. 304 which on test withstood an internal pressure of 12,500 psi.
4. Approximately 44,000 jettison tank brackets of Alloy D.T.D. 298.

Heat resisting steel turbine blades were produced by utilizing a vacuum process which yields a casting free from air contamination.

D. C. Williams



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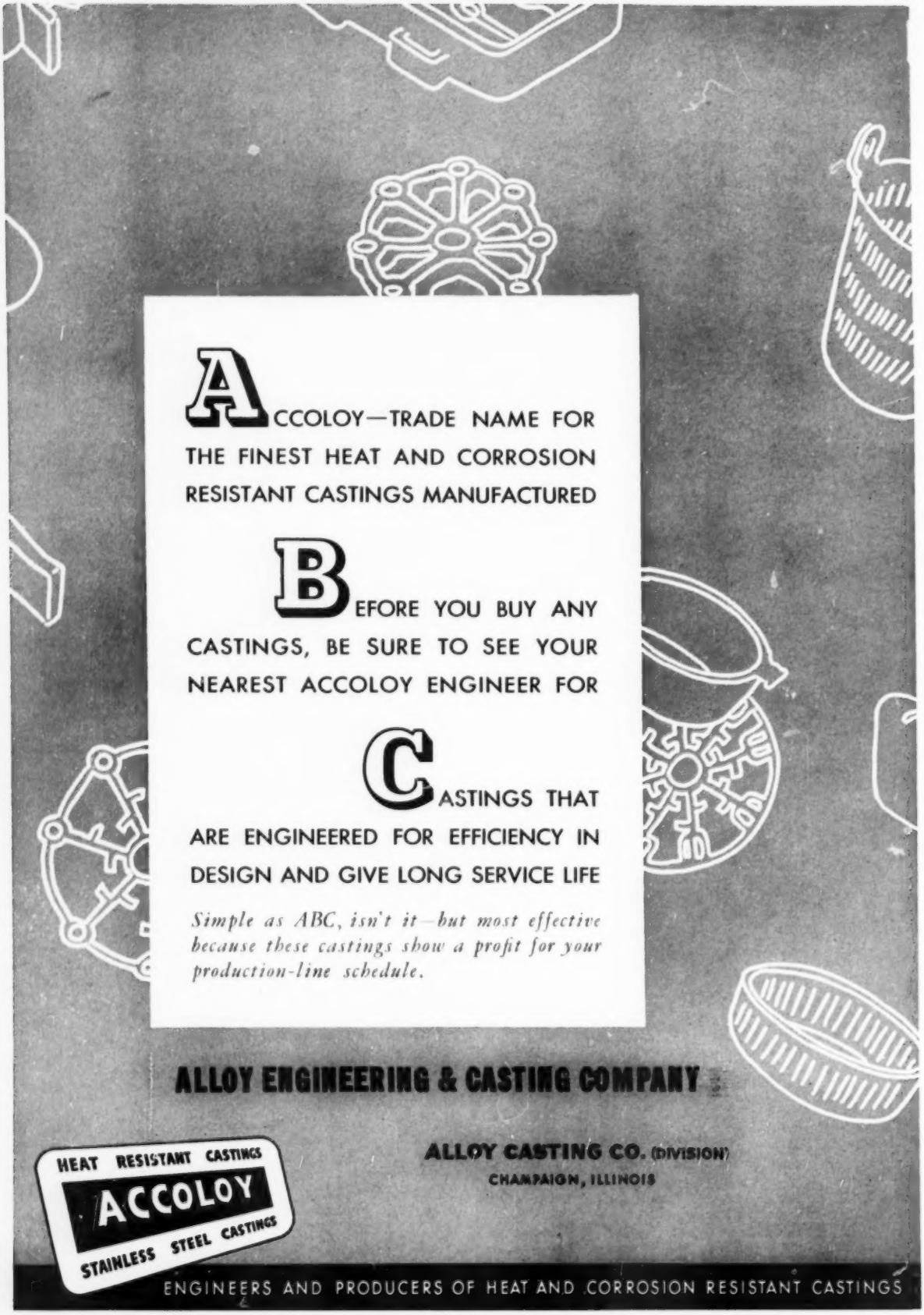
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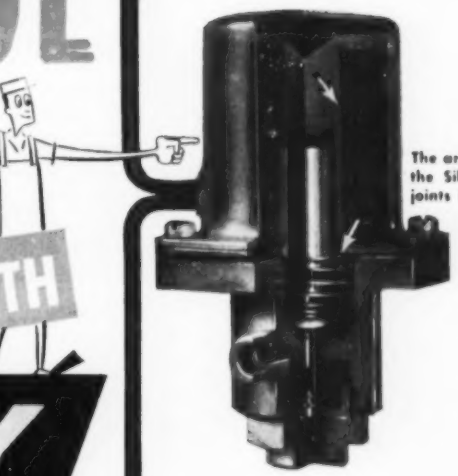

The arrows point to the Silvaloy-brazed joints in this interior view.

The successful manufacture of electromagnetic units such as solenoid valves calls for the reliable standards of engineering and precision production that have ranked the McQuay-Norris name high on the list of manufacturers of industrial components.

The cut-away illustration is an interesting view of a McQuay-Norris Solenoid Valve. Two interior points that are brazed successfully with Silvaloy and APW Flux are shown on the sectional area.

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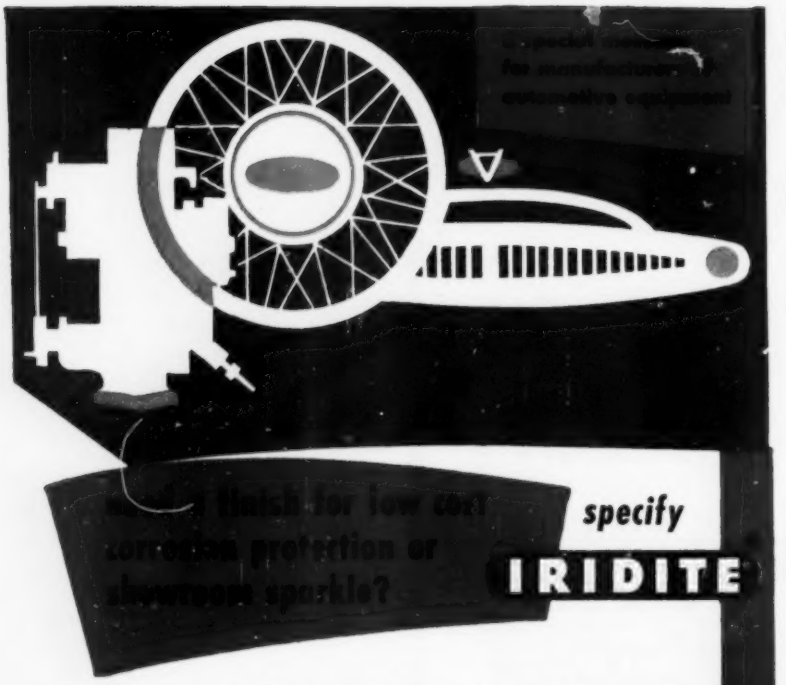

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Effect of Elevated Temperatures on Drawing Operations*

THIS INVESTIGATION covered the drawing operations on mild steel wire at temperatures up to 1150° F., while the second part of the paper describes the drawing of similar mild steel wire at temperatures as low as –97° F.

The possible advantages of hot drawing include: (*a*) superior mechanical properties; (*b*) variations for the elimination of aging characteristics; (*c*) lower power consumption; (*d*) spontaneous recrystallization. These advantages have already been realized in rolling operations at elevated temperatures, where lubrication is not a problem, but there is little information available regarding the effect of elevated temperatures for the drawing of patented wire up to 570° F., although considerable work has been done in the neighborhood of 300° F.

Although three types of draw benches were used in this study of the hot drawing of steel wire, practically all of the work was done on a live-load drawing machine similar to what might be encountered in the normal manufacture of wire. The reel of undrawn wire was placed in a furnace heated by gas after the wire had received the lubricant selected for the drawing test. The wire from this reel, coated and heated to the drawing temperature, passed through an electric resistance tubular furnace which was operated at the drawing temperature. At the opposite end of this furnace the drawing die was placed and likewise heated to the drawing temperature. The drawn wire, on leaving the die, passed over another reel and the pulling was done by ¼-hp. motor through suitable reduction gears.

The hot drawing was performed in stages from room temperature to a maximum of 625° F. All drawing dies, of standard carbide type, withstood the temperatures satisfactorily. The force generated in the drawing

(Continued on p. 132)

★Digest of "The Drawing of Steel Wire at Elevated and Subnormal Temperature", by F. C. Thompson, J. B. Carroll and E. Bevitt; *Journal* of the Iron and Steel Institute, Vol. 173, January 1953, p. 36-50.

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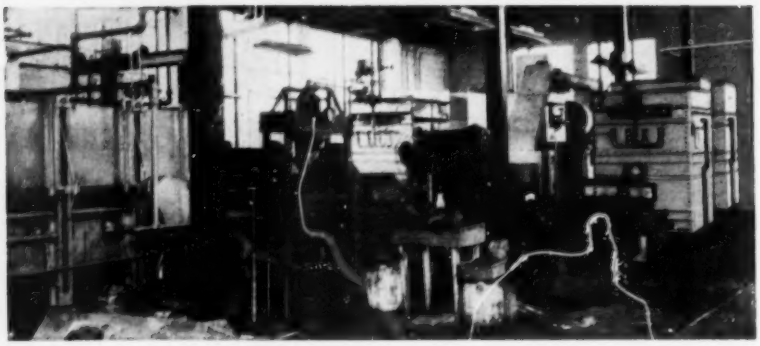

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Effect of Elevated Temperatures on Drawing Operations

(Continued from p. 130)

operation was measured by a statimeter unit attached to the drawing die.

The measurement of the temperature of wire being drawn at a fairly high speed presented considerable difficulty; the most successful method for this employed thermocouple wires brazed to a copper strip which rested on the wire immediately before it entered the die. It is stated that the temperature measurement is probably accurate within ±18° F.

The material used in the live load test with this apparatus was bright annealed low-carbon wire having an original diameter of 0.0475 in. This wire was degreased by rubbing with cotton wool soaked in benzene before an even coat of lubricant was applied. The amount of draft varied from 10 to 16% reduction of area in the high-temperature drawing.

The main problem in the successful hot drawing operation was found to be related to the lubricant used. Most of the lubricating agents tried were unsatisfactory at temperatures above 212° F., due either to decomposition of the components, evaporation of the carrier fluid, or peeling of the lubricant coating from the hot wire.

Lead – Although successful as a cold drawing lubricant for alloy steel, lead was quite unsuitable for high-temperature wiredrawing. The difficulty of wetting the wire in the lead bath may be the cause of this, and the use of several fluxes gave no improvement. The lead-tin eutectic alloy was also unsuitable. (NOTE: This conclusion regarding lead is quite surprising since lead coatings either applied chemically or by hot dipping have been very satisfactory for the drawing of alloy tubing at high temperatures.)

Copper – At room temperature, a chemically deposited copper coat is very satisfactory. However, when the deposit dried, it peeled off and at temperatures above 300° F. oxidized and scored the die. Copper deposited electrolytically on a graphite undercoat showed some improvement.

Aluminum and Calcium Stearates

(Continued on p. 134)

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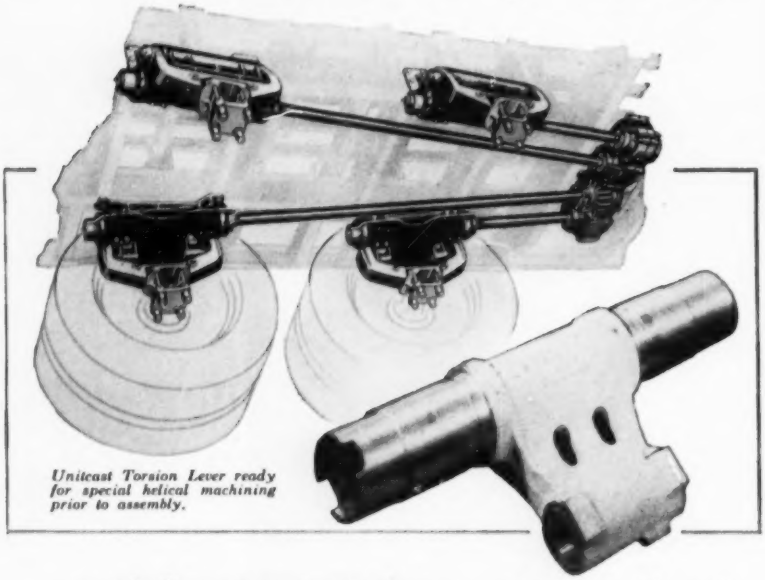

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QUALITY STEEL CASTINGS

Effect of Elevated Temperatures on Drawing Operations

(Continued from p. 132)

—A single coating of lime gave very irregular drawing loads, but wire which had been lime coated and dried four successive times showed very good improvement with the use of stearates to about 390° F.

Silicones — Two types of silicones, used alone or with other greases, decomposed at temperatures around 390° F. At 680° F. the drawing load with these was over twice the load at normal temperatures.

Hydrocarbon Oils — Various heavy oils and greases with a petroleum base were tried. All of these, with the exception of one special oil whose composition is not given, decomposed at temperatures in the neighborhood of 390° F.

Phosphate Coatings — Three of these were Bonderized and one was Parkerized. When these coatings were used without lubricants, it was found that they were useless for high-temperature drawing. The authors intimated that thin deposits of phosphate coatings underneath a superior lubricant might have some advantage, but no data are given to support this conclusion.

Graphite Dispersions — This group included such mixtures as graphitized wax and colloidal graphite in lanolin. Since the oil or wax base charred below 390° F., this produced an unworkable deposit on the wire. Aquadag (graphite in water) presented difficulties in producing a uniform wetting of the wire, even with the use of a detergent. Drawing at a reduction of 10% was smooth up to 900° F. but considerable corrosion of the wire occurred. Other colloidal graphite deposits were more satisfactory and the best compound encountered was colloidal graphite dispersed in naphtha. This lubricant enabled smooth drawing up to 1065° F., and a minimum drawing load up to 660° F. Dispersions of mineral compounds such as talc and mica were unsatisfactory.

Satisfactory drawing of wire at high temperatures depends almost entirely on the use of a lubricant which will be stable at the drawing temperature employed. Thus, lubri-

(Continued on p. 136)

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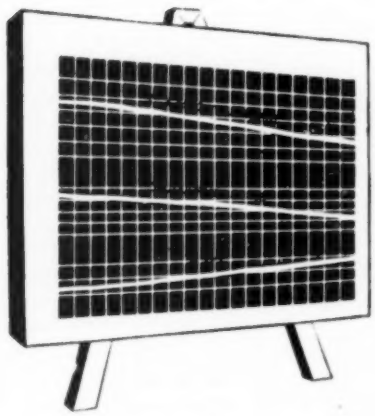

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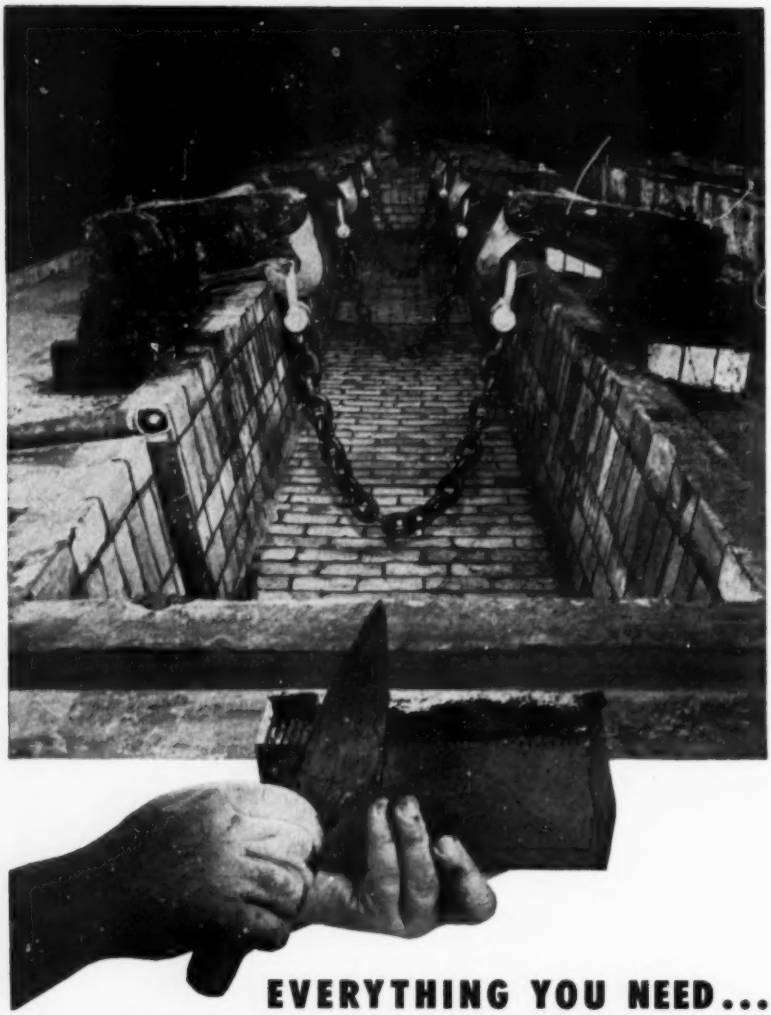

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Effect of Elevated Temperatures on Drawing Operations

(Continued from p. 134)

cating compounds which decomposed below the drawing temperatures were completely unsatisfactory. These tests indicated that some of the silicones and stearates might be usable up to 570° F., but the only material which could be employed in the range of 570 to 1110° F. would be one of the colloidal graphite lubricants.

In most of the tests the drawing load decreased to a minimum below the load encountered at room temperature, but then rose to a maximum at some higher temperature wherein the lubricating properties began to fail. The factors influencing the drawing load are believed to be the amount of friction, the hardness of the wire and aging of the wire under the conditions of cold forming and reheating extant. Since aging mostly occurs in the range of 300 to 570° F., drawing conducted at temperatures above this would eliminate that factor. The yield strength decreased rapidly when the steel was drawn above 750° F.

The mechanical properties of the hot drawn wire were surveyed. Maximum tensile strength was obtained in wire drawn at 250° F., and the maximum elongation was developed at 300° F. Some of these tests were made after the wire had aged for 10 months in order to get some idea of the aging effect. Although the tensile test data are quite inconsistent, the authors state that the wire drawn at the lower temperatures seems to harden and age, and the wire drawn at higher temperature (above 390° F.) tends to soften. There are no tensile tests given for wires drawn above 750° F. From these tests it is evident that there is very little recrystallization on the wire drawn below 750° F.

The drawing load at room temperature for a reduction of area of 10 to 12% was 18 to 45 lb., depending on the lubricant used. A minimum drawing load appeared to occur in the range 300 to 570° F., with the graphite lubricants. Above 570° F., the drawing load usually increased steadily up to 1110° F.

E. C. WRIGHT

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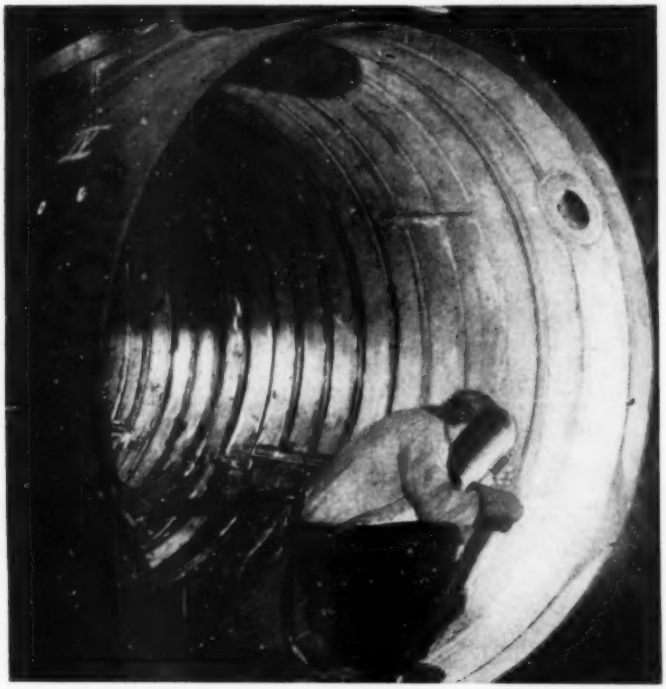

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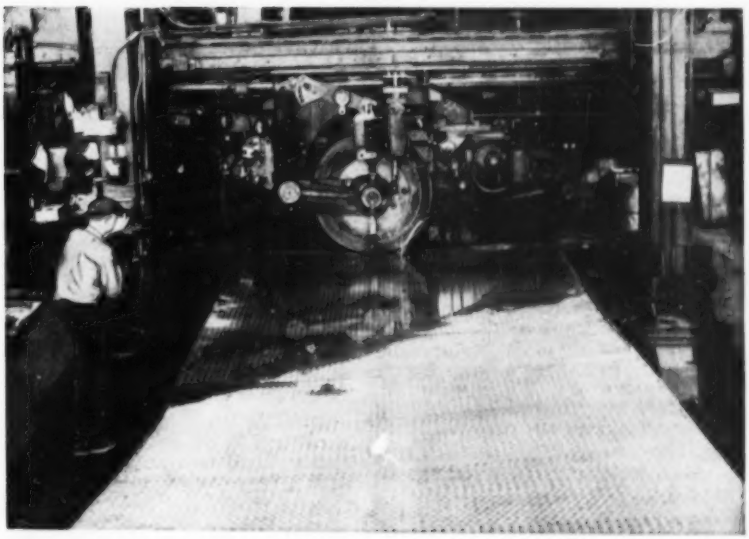

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Oxidation Resistant Copper Alloys*

IN THIS REPORT, the authors give the results of their study of the rates of surface oxidation and the nature of the scales formed for a series of copper-base alloys. These were binary alloys, containing small additions of aluminum, beryllium, chromium, magnesium and silicon, and the data on these is presented in the form of curves which show the rate of increase in weight per square centimeter of specimen surface after exposure to ordinary air at various temperatures and times.

Besides these data, the results of chemical analyses of the scales are plotted in terms of percentage of copper occurring as cupric oxide in the scale layer. Also, for certain of the alloys, the percentage of the alloying element found in the scale is reported. Interesting details of scale layers on certain specimens are shown in photomicrographs. The temperature range was from 750 to 1830° F. and the exposure varied from a few to 100 hr.

The authors have concluded that the effectiveness of the various elements in protecting the copper from scaling was in decreasing order as follows: beryllium, aluminum, magnesium, silicon and chromium.

The behavior of each alloy is discussed separately. Aluminum alloys ranging from 2 to 10% aluminum were used. The rate of oxidation is greatly reduced as the aluminum content increases; above 4% aluminum the rate is quite low. With these alloys scaling proceeds quite rapidly until a protective film of alumina is formed at the scale-metal interface, and this film then effectively checks further oxidation. The authors devote a good portion of their paper to a discussion of the scaling of the 2% aluminum alloy. In the range from 750 to 1450° F. the scale at first consists of cuprous oxide interspersed with alumina. Gradually cupric oxide replaces the cuprous form. Above 1605° F. cupric oxide

(Continued on p. 140)

*Digest of "High-Temperature Oxidation Characteristics of a Group of Oxidation Resistant Copper-Base Alloys", by J. P. Dennison and A. Preece, *Journal* of the Institute of Metals, Vol. 81, January 1953, p. 229-234.

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	Cleaning	"DEOXIDINE" "DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
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CHEMICALS ACP PROCESSES

Oxidation of Copper

(Continued from p. 138)

is unstable and the scale then contains only cuprous oxide and alumina. Subscale is apparent below 1350° F. but not above. This seems to be a significant feature of scale formation. At higher temperatures and especially with higher aluminum contents, alumina forms so rapidly and continuously at the scale-metal interface that oxygen penetration is effectively checked and scaling rate rapidly decreases.

Alloys containing 1 and 2% beryllium were studied, and this element was found very effective in checking oxidation. Apparently, the mechanism is similar to that of aluminum, but it becomes effective at lower concentrations. The higher the temperature, the more rapidly is a protective scale formed. The 2% alloy gives excellent protection over the entire temperature range studied.

Chromium in the concentration studied (1.2%) does not afford any protection to copper against scaling. There is a pronounced tendency to form subscale at the higher temperatures. The authors conclude that the solid solubility of chromium is too low to give a sufficient concentration for the rapid formation of a continuous film of chromium oxide.

The magnesium alloy used contained 1% of this element. This did not give effective protection except at the higher temperatures. Subscale formation was extensive below 1350° F. but slight at higher temperatures.

Two silicon-bearing alloys were used, namely 2 and 3.5% silicon. Subscale formation takes place below 1350° F. Also, a film of silica is found at the scale-metal interface at temperatures up to 1470° F. Above 1650° F. silica did not occur in the scale but instead there was an increase of silicon in the alloy layer immediately below the scale. This behavior is peculiar and no explanation for it is given.

The authors conclude that the effectiveness of an alloying element in reducing the rate of scaling of copper requires the formation of a separate and continuous layer of the oxide of that element at the scale-metal interface. Preferential oxidation of the alloying element seems to be essential, but under conditions

(Continued on p. 142)

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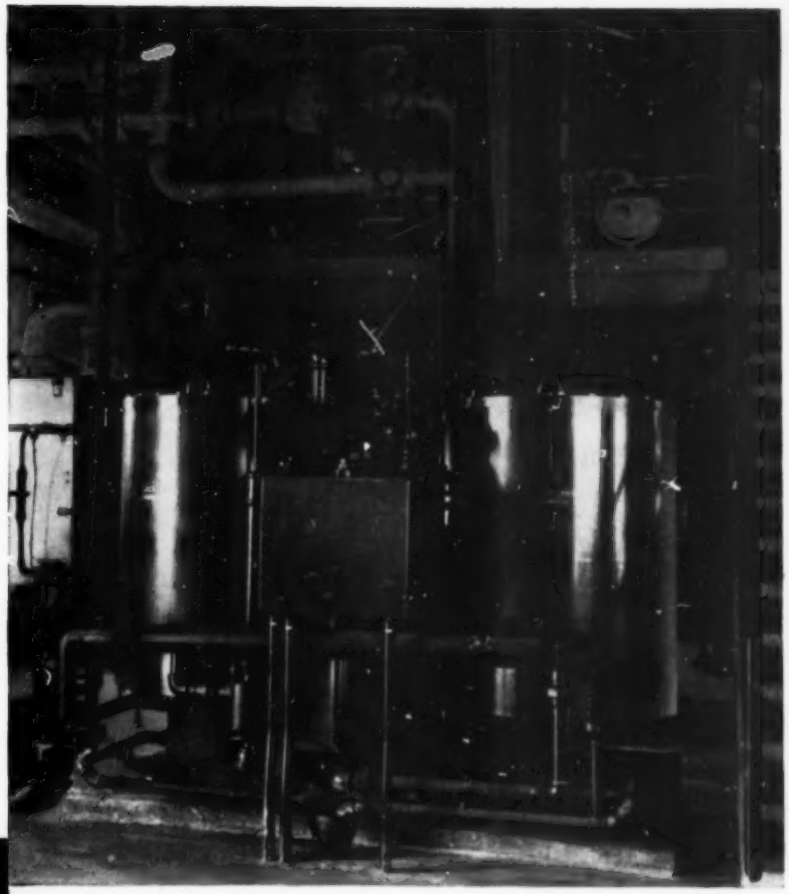

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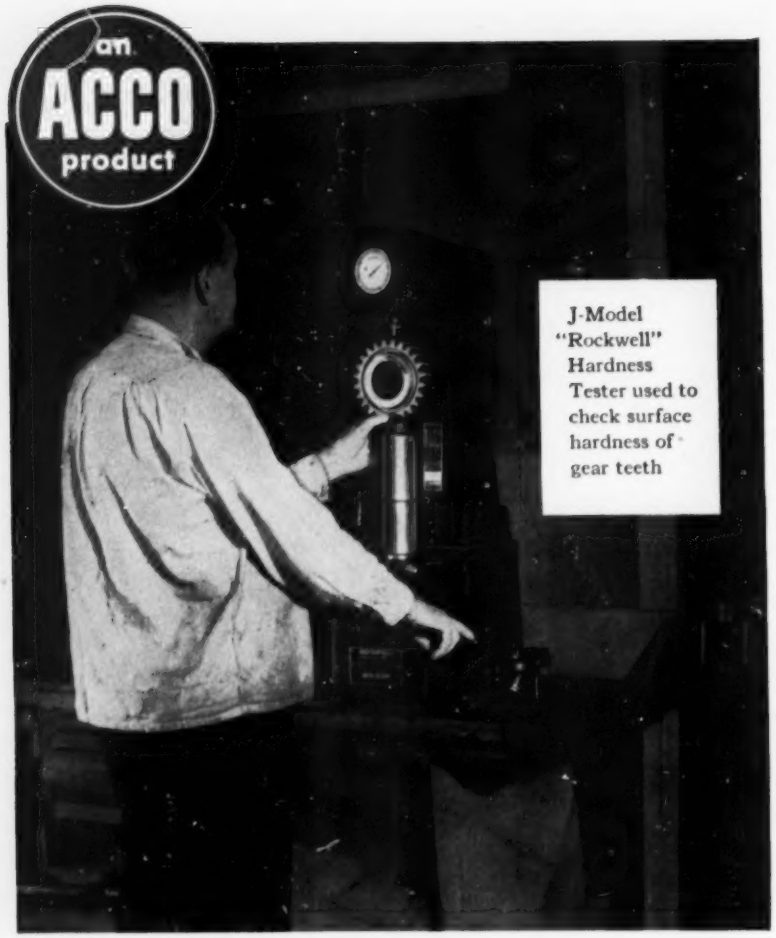

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WILSON "ROCKWELL" and TUKON Hardness Testers

Oxidation of Copper

(Continued from p. 140)

where subscale is forming no such protective film is produced.

The authors have assembled some valuable data. When consideration is given to the small weight increments which they had to determine, the consistency of their curves is remarkable. PHILIP H. KIRBY

Advantages of Silicon Capping*

STEEL FOR wire rod in the carbon range 0.06 to 0.25% is capped rather than fully rimmed so as to decrease segregation, increase the yield and control the skin thickness. Slag condition, deoxidation practice, tapping temperatures, and pouring rates must be at the proper value to produce acceptable capped ingots.

The slag directly affects sulphur and oxygen, which are related to rimming action. Below 0.20% C, a lime-silica ratio of 2.5 is sufficient to promote good rimming action. For heats finishing from 0.20 to 0.25% C, a ratio of 2.8 is preferred. The addition of aluminum to the ladle is based on the specification for carbon and manganese rather than on the FeO in the slag; this addition varies from 0.27 lb. per ton for carbon contents of 0.10% and under, to 0.10 lb. of Al per ton for heats of 0.20 to 0.25% C. In order to increase skin thickness and decrease segregation, heats are tapped on the low side of the temperature range, and the latter in turn depends upon the carbon content.

The pouring rate should be slow enough to allow rimming to start before the mold is completely filled. This factor is especially important in ingots from 75 to 85 in. high because the ferrostatic pressure tends to suppress active rimming action. The practice of silicon capping is devised to retain the advantages of capped steel over both rimming and killed steel, and avoid the limitations of mechanical capping.

The heat is worked, tapped and

(Continued on p. 144)

*Digest of "The Manufacture of Silicon Capped Steel", by Albert Lami, a paper presented at the Pittsburgh Regional Technical Meeting of the American Iron and Steel Institute, October 16, 1952.

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Silicon Capping

(Continued from p. 142)

deoxidized by normal practice for making rimming steel. It is teemed into open tapped big-end-down molds, with aluminum added as necessary to produce a slight drop-center rimming action. After the steel has rimmed for the length of time to produce the desired skin thickness, from 0.4 to 0.65 lb. per ton of fine 75% ferrosilicon (from ⅜ in. down to 12-mesh size) is added. This kills the rimming action so that the steel forms a natural cap by freezing across the top. Finer silicon forms lumps; larger sizes dissolve too slowly.

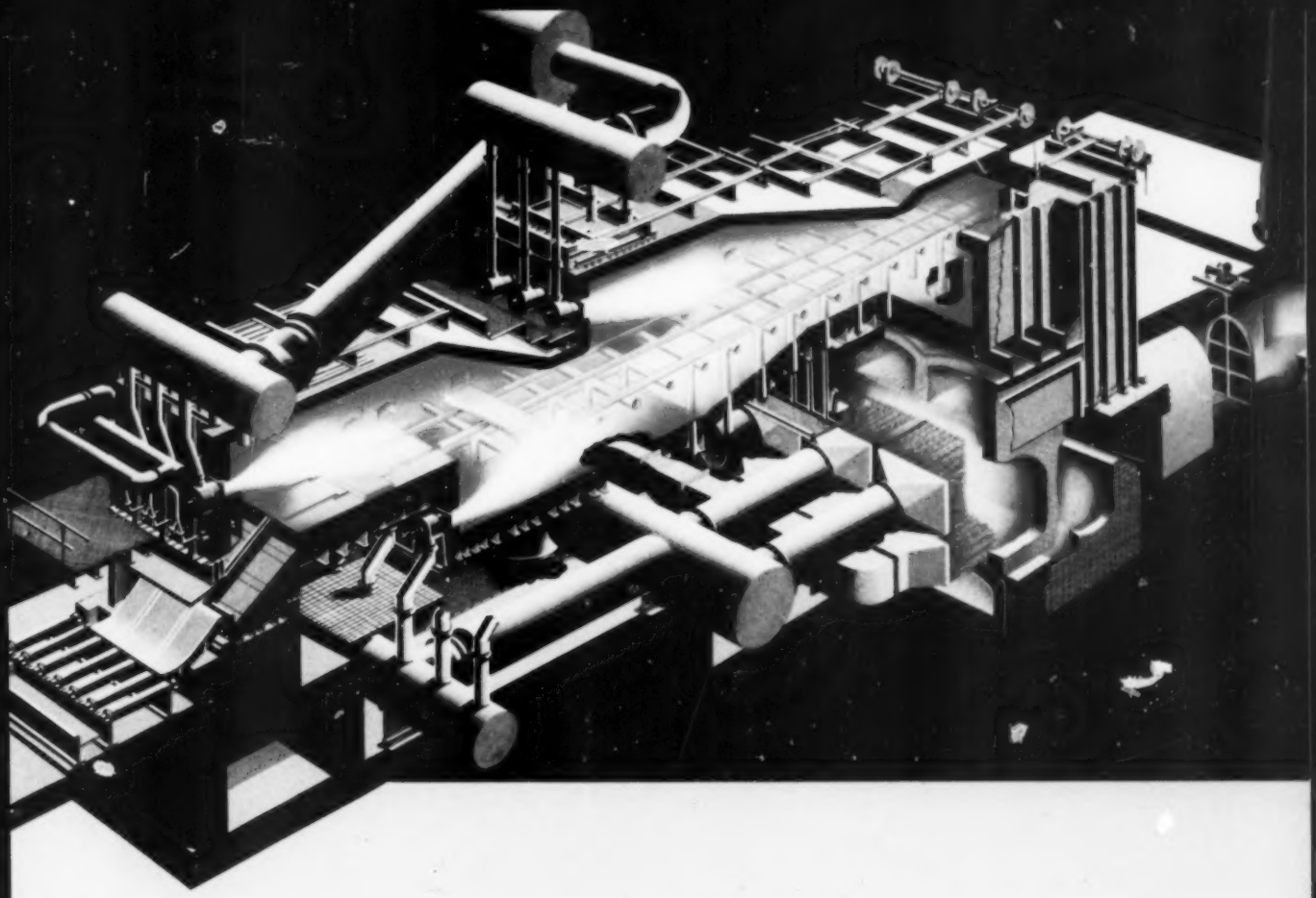
After the temperature drops sufficiently, the change in the carbon-iron oxide equilibrium causes rimming to start again in the molten portion. The pressure formed causes a slight bleeding, and this furnishes a visual indication that the ingot is not over-deoxidized and that piping is at a minimum. Thus, a silicon-capped ingot is produced with the same characteristics as a bottle-topped ingot and with the practical advantage that the ingot weight may be varied simply by changing the height of pour.

The time between finish pour to the silicon addition determines the amount of rim zone formed and is under more direct and accurate control than is the time for a mechanical capped ingot to rise to hit the cap. The required amount of silicon per ton increases with increasing ingot section. With 22x24-in. ingots, capping is begun using ⅜ lb. per ton and the amount is then adjusted on succeeding ingots.

In general, silicon capping is preferred to mechanical capping when better control of skin thickness and segregation is required. The difference in anlaysis from top to butt is much less in the 1 and 3-min. silicon-capped ingots than in the 5-min. silicon-capped or in the rimmed heats. A carbon segregation of 0.015 to 0.03% is usual in the 1-min. silicon-capped practice.

With silicon capping, the yield is the same as with mechanical capping, but the skin of improved quality and predetermined thickness results in decreased scrap loss and lower reconditioning cost.

F. G. NORRIS



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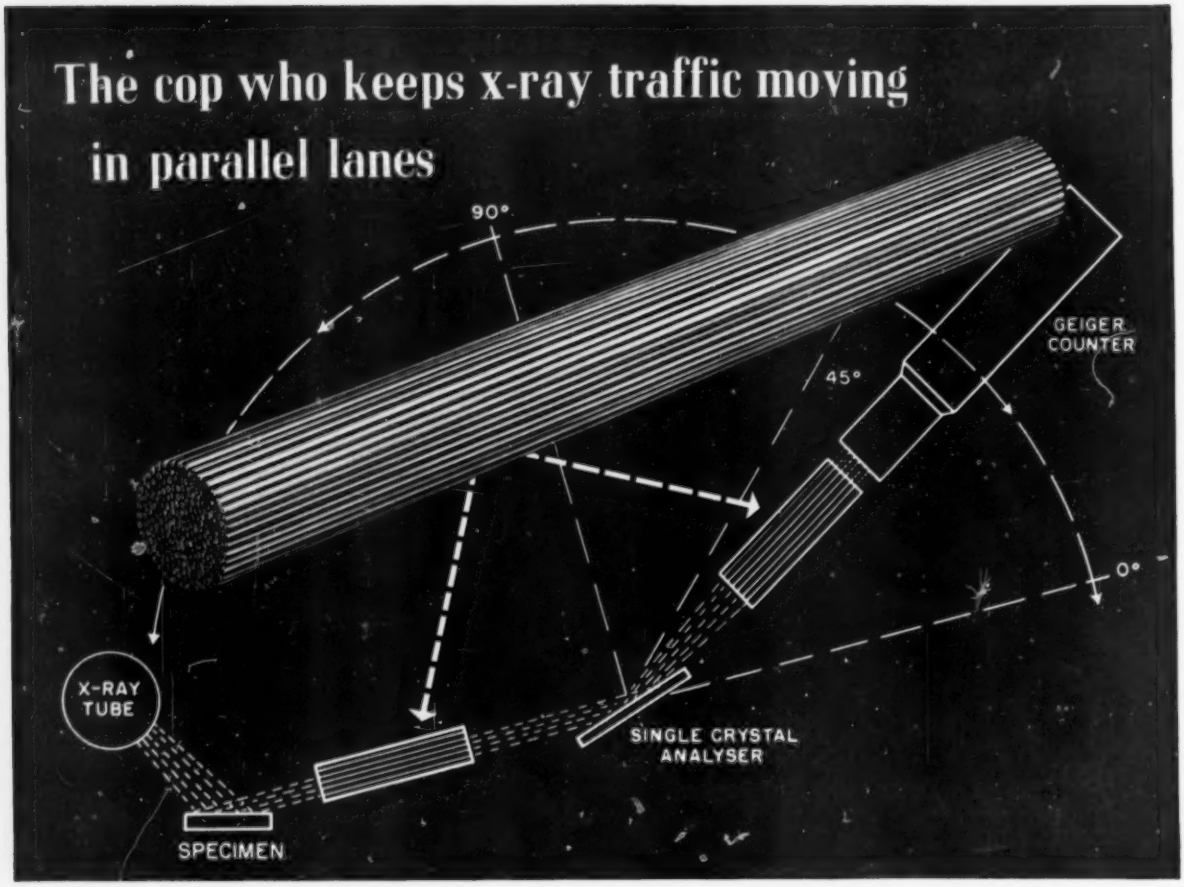

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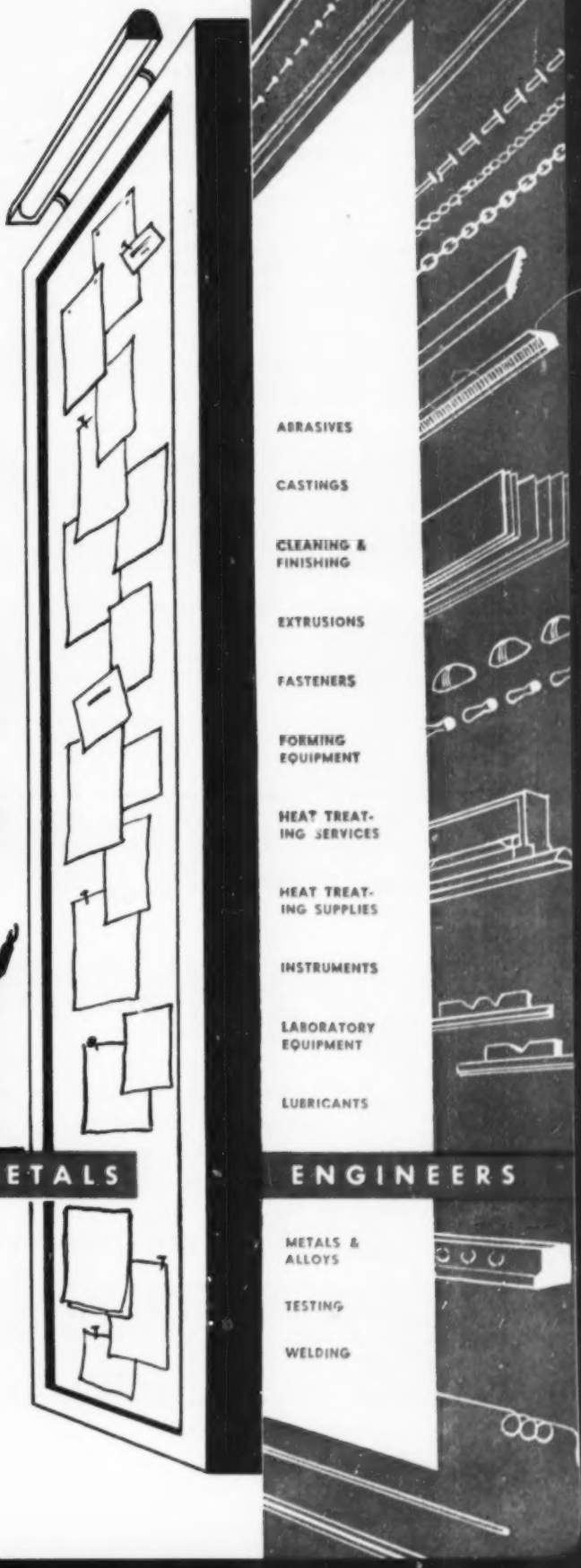

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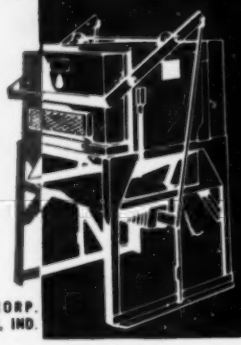

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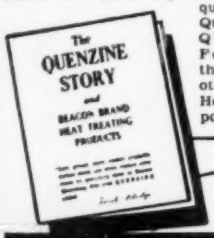

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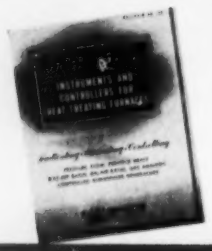

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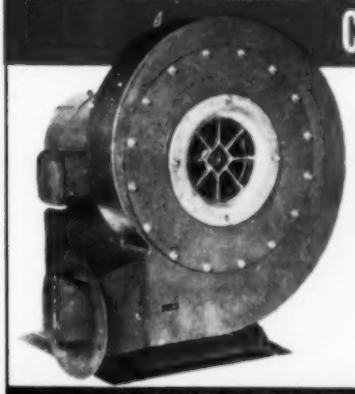

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HEAT TREATING FURNACES

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FOR . . . .

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Sure-Wear *Heat Treating*

"Sure-Wear"—to ensure longer life in all types of high speed cutting tools!

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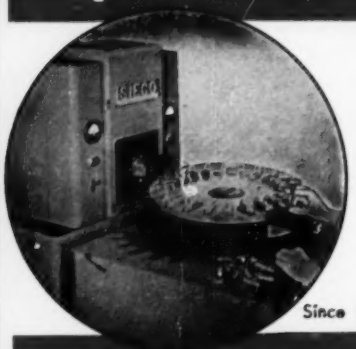

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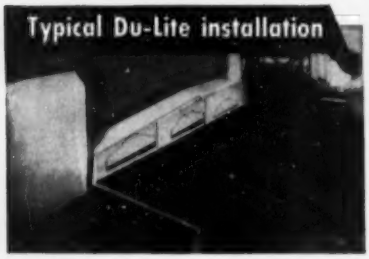
Courtesy The Poly Choke Co.

Du-Lite gave this part with its complicated knurls, slots, threads, etc. a fine rust-resistant durable black finish. It is typical of many other parts, small and large, which have been black oxidized by Du-Lite for many years. Moreover, Du-Lite meets most individual and government specifications including 57-0-2C for Type III Black Oxide finish.



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of any size and shape — any ductile metal

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- ★ Faster, more Uniform Blackening
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Send for **FREE** Literature on Swift **BLACK** and Cleaning Compounds **TODAY!**

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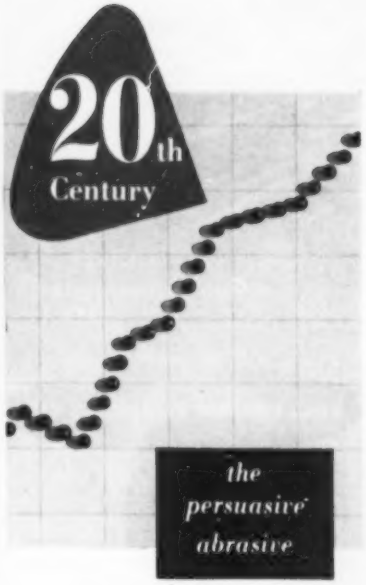

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Built for Heavy-Duty Long-Life Service

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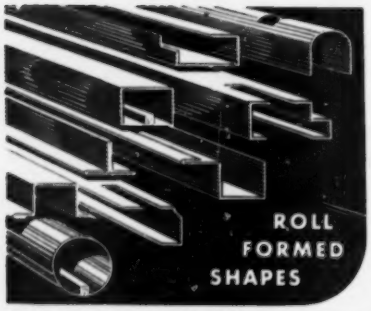

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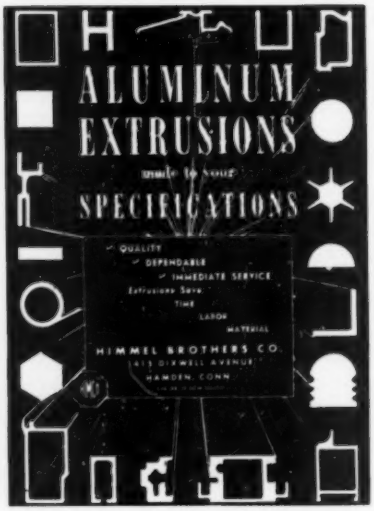

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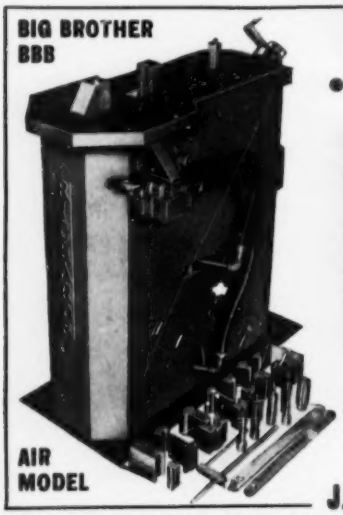

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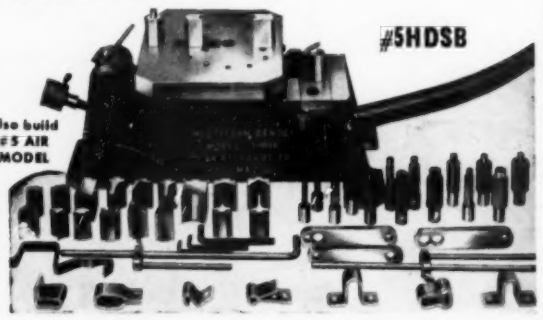

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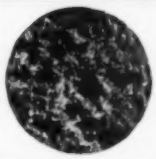	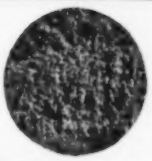

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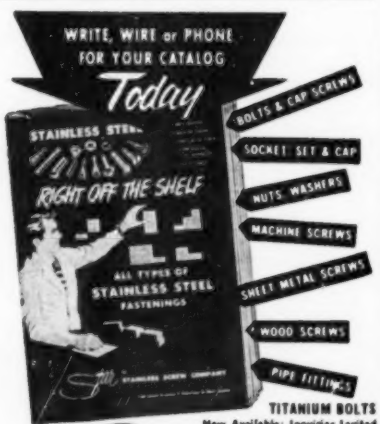

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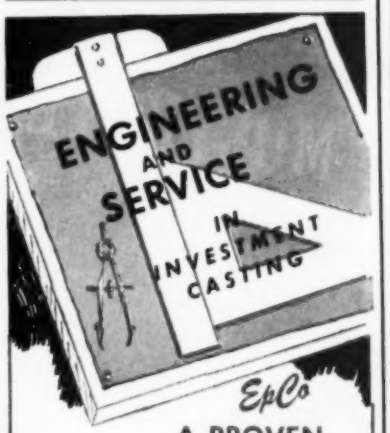

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FREE
Cutting Oil Chart

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Steel and nonferrous metals are charted with the proper cutting oil for many applications. Shows you how to use lubricants, sulphurized or compounded with extreme pressure additives, for all operations.

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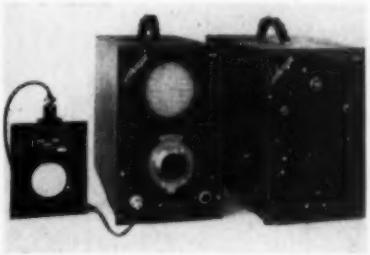

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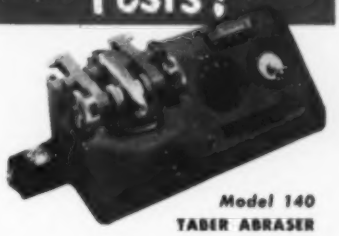

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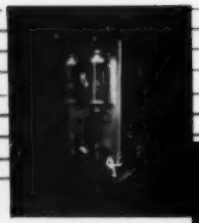

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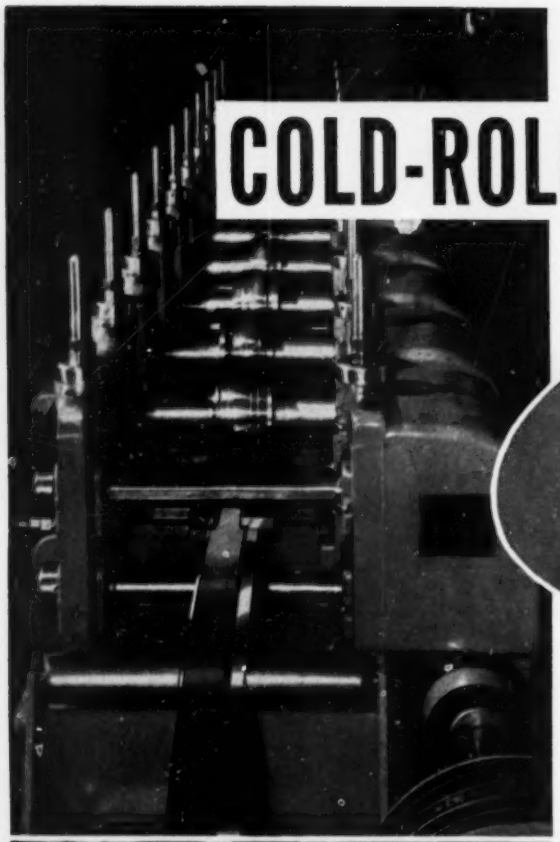

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•

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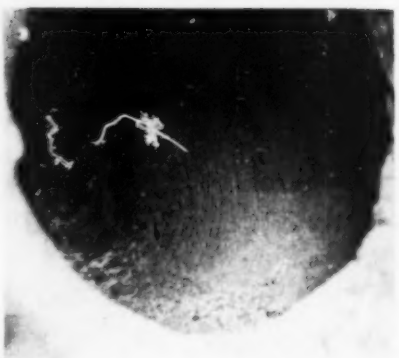
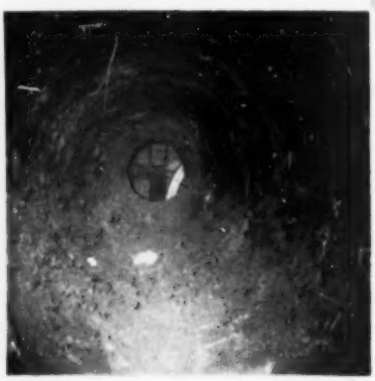


Photograph shows the TASIL brick and shape lining of a 2-ton rotary furnace *after three years* of intermittent service. Over 1,000,000 lbs. of monel and copper-nickel alloys were melted in this lining. There is no evidence of wear or joint erosion. The original 32" inside diameter has been maintained.



This photograph shows the condition of a *fireclay brick lining* after 15 months service in a 5-ton rotary furnace operated by the same manufacturer, in the same foundry, as furnace in photo above. Approx. 730,000 lbs. of low melting point alloys were melted. Service of this furnace was less severe, as very few copper-nickel heats were melted. Note extreme slagging. Lining has lost 2" to 3" in vulnerable areas.

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By STEWART G. FLETCHER
Chief Metallurgist
Latrobe Steel Co., Latrobe, Pa.

Introducing: the New Self-Lubricating High Speed Steels

HIGH SPEED STEELS have reached a relatively advanced stage of development, and their alloying characteristics, heat treatment, metallography, properties and methods of use are well known. Among the major improvements in the last decade or so have been the development of molybdenum high speed steels, the addition of vanadium (with carbon) for better tool life, improvement in manufacturing techniques to control segregation and other inhomogeneities, and great strides in understanding and development of heat treating techniques.

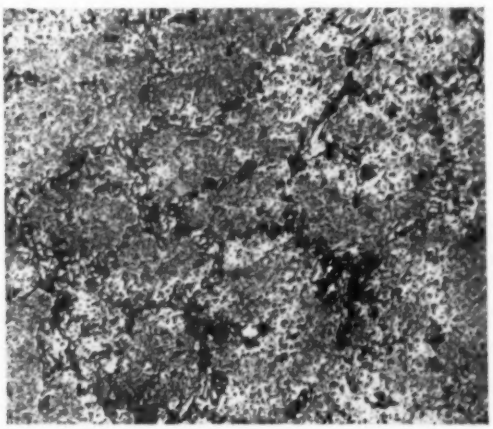

Fig. 1 – Microstructure of Cast and Annealed M-2 High Speed Steel Containing 0.85% S. Note the gray sulphide particles which solidify as part of the carbide-austenite eutectic. Picral etch; 250×

Despite all this research by producers, consumers, and independent laboratories, two potential fields of improvement have remained untouched:

1. Development of a method to improve cutting efficiency by providing lubrication within the tool itself, thus reducing the frictional forces which generate heat in cutting.
2. Improvement of machinability so that tools can be more easily fabricated.

A lengthy study of both of these problems has been made in the research laboratories of Latrobe Steel Co. The result of this research has been the introduction of a series of what we call "self-lubricating" high speed steels, in which improved machinability and internal cutting-edge lubrication are obtained.

It has long been known that molybdenum disulphide has striking lubricating properties. It has likewise been known that sulphur, usually in the form of manganese sulphide, when added to low-alloy steels produces good machining properties. High speed steels are relatively low in manganese, and additional manganese above about 0.50% will lower the Ms point unduly, resulting in large amounts of retained austenite. It was evident very early, therefore, that manganese sulphide would not provide the desired effect. It was found, however, that sulphur, added to the melt as MoS_2, FeS_2 or elemental sulphur, is soluble in molten high speed steel of the S.A.E. – A.I.S.I. types M-1, M-2, M-3 and M-10 to at least 2%. In amounts less than 1%, it is believed that the sulphide solidifies as part of a complex carbide-austenite eutectic. (The composition of this sulphide has not yet been positively established.) Because of its introduction into the carbide-austenite eutectic, the

sulphide appears to be closely associated with the carbides, as evident in Fig. 1. This close association persists during forging, rolling, and heat treating.

It was early realized that a well-founded resistance to the addition of a sulphide phase to high speed steel might be encountered in the trade, which would naturally stem from the deleterious effect of nonmetallic stringers on fatigue life and other properties of hardenable steels, and the feeling that addition of sulphur would add measurably to this effect. Actually, however, because of our present ability to disperse carbide segregation in high speed steel, and the close affinity of the sulphide with the carbide, the sulphide additions described here are small and well-dispersed (see Fig. 2). They have only a mild tendency to form long, continuous stringers, and this tendency is evident only at high sulphur contents (above about 0.20%), or in the presence of an abnormal number of oxides, which are the usual cause of stringer formation.

Another anticipated difficulty was the possible damage to the forgeability and other hot forming properties of high speed steel. Some of the early heats did have rather poor hot working properties, showing corner tears and other surface ruptures. However, it has been found that if the sulphur content is not too high, and melting and casting conditions are properly controlled, the decrease in workability is fairly small. The surfaces of billets after first forging require considerably more conditioning, so that actual recovery of bar from ingot is reduced a few percent as compared to the normal molybdenum high speed steels without sulphur addition. As experience is gained in melting, casting, forging, rolling and drawing these self-lubricating high speed steels, mill recoveries are gradually improving, but it is doubtful that they will ever be as good in production as the conventional low-sulphur high speed steels.

Table I – Comparative Impact Strength of M-2 Steel With and Without Added Sulphur

Tempering Temperature	Rockwell Hardness	Izod Impact*	
		0.018% S	0.14% S
	Hardened at 2200° F.		
950° F.	C-65	30 ft-lb.	32 ft-lb.
1000	65	47	42
1050	64	43	43
1100	61	48	44
	Hardened at 2250° F.		
950° F.	C-66.5	21 ft-lb.	29 ft-lb.
1000	66	41	38
1050	65	39	37
1100	63	32	27

*Unnotched

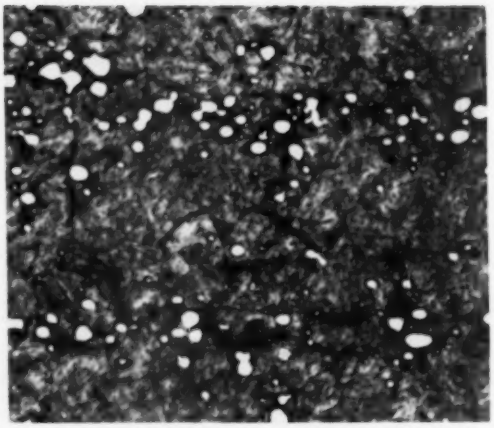

Fig. 2 – M-2 High Speed Steel Containing 0.13% S; 1¼-In. Round Bar, Heat Treated. The gray sulphide particles can be clearly seen in close association with the primary carbides. Picral etch; 1000×

The optimum amount of sulphur for the best combination of machinability, self-lubrication, formability and mechanical properties after heat treatment is somewhere between 0.08 and 0.20%. The present aim is 0.12%, and promising results have been obtained on material made to this specification.

TOOL PERFORMANCE

Tools made of this new type of high speed steel have invariably shown improved cutting efficiency from the lubricating action of the sulphide particles in the matrix of the steel. Tool wear is consequently reduced, and instances have been reported in which the amount of grinding for resharpening has been drastically reduced because of the slower development of wear lands. At the same time it has frequently been possible to increase cutting speeds, for there is a "greasy" action which effectively reduces the amount of heat generated at the cutting edge.

As all metallurgists know, it requires an extended series of precisely controlled experiments to determine quantitatively the "machining ability" of a given toolsteel. Such comprehensive tests are now in progress. Until these data are available we can only report some findings of customers who have run preliminary tests in their own toolrooms or laboratories.

(Continued on p. 164)

Production Records Prove *Talide Dies* Save You Money

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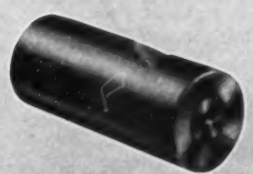

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CURLING ROLLERS

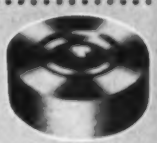
Large Can Company reports TALIDE Curling Rolls last 65 times longer than steel rolls on beverage can forming operation—with edges free from burrs and cracks.

POWDER METALLURGY DIES

Large Pharmaceutical Company reports TALIDE Pill Dies not only produce tablets having a superior surface glaze which reduces rejects 62%—but also outlasts steel dies 100 to 1.

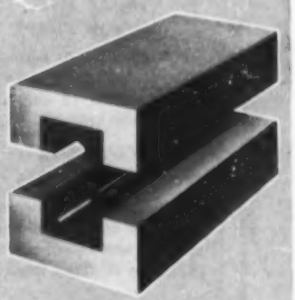
TUBE MANDRELS

12 days (36 shifts) of continuous trouble-free production obtained by eastern Brass Mill with TALIDE Tube Drawing Mandrels—compared to average 6-hr. runs obtained with steel mandrels.



DRAWING DIES

50 miles of tough 5" alloy steel tubing (actually 252,000 ft.) drawn by large midwestern Steel Mill through TALIDE Tube Die compared with a normal run of 10,000 ft. with a steel die.



SWAGING DIES

Leading Fountain Pen Manufacturer cold swages an average of 750,000 stainless steel sleeves with TALIDE Swaging Dies — 33 times more than with chrome-plated dies.

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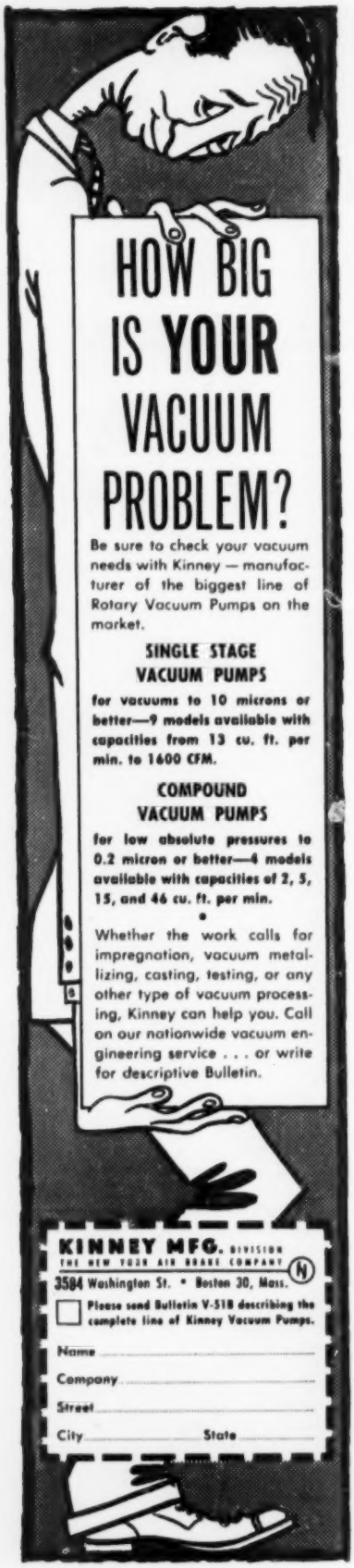
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The New Self-Lubricating High Speed Steels

(Continued from p. 162)

Gear Hobbing – Three M-2 hobs of normal composition (6-6-2 W-Mo-V) were run on a standard gear hobbing operation in an automotive plant, in competition with three hobs made from M-2 with 0.12% sulphur. After regrinding the hob cutters an average of ten times, it was found that the average stock removal per grind (a direct measure of the amount of wear) for the standard M-2 was 0.017 in. while the self-lubricating M-2 was ground an average of 0.0085 in. This indicates at least double the tool life because of the reduced formation of wear lands.

Single Point Tool – This test was on 5/16-in. square ground tools, taking a 0.050-in. deep cut on the end of a 12-in. Meehanite log (221 Brinell) with a 3-in. hole. This was done on a lathe at 50 rpm. with 0.021-in. feed. The "number of inches cut" is regarded as the distance from the inside diameter to the point where the cutting edge of the test tools breaks down, and the "surface feet" is the speed at this point.

The average of three tests on regular M-2 was 3.021-in. cut and 113.3 surface ft. per min. On the self-lubricated M-2, the average inches cut was 3.405 and the surface feet, 125.8. This represents an increase in performance of 12.7% in inches cut and 11.0% in surface feet.

MACHINABILITY

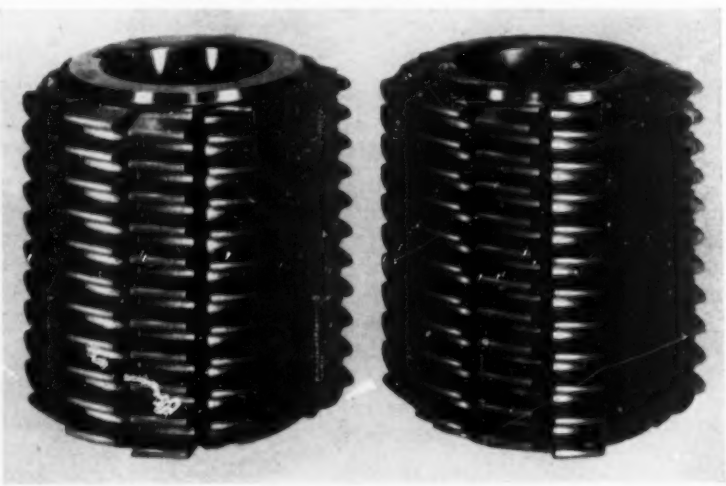
Sulphide additions improve machinability of the toolsteel itself by a different mechanism than that of manganese sulphide in the low-alloy steels. In the latter, machinability is improved by the action of the rather large, stringy manganese sulphide particles breaking up the chips as they are produced. In the sulphur-treated high speed steels the action is more one of internal lubrication; higher cutting speeds and better machined surfaces are attained without materially affecting the type of chip generated.

One of the outstanding contributions to machinability has been the improvement in surface finish obtained by relief machining such as is required in the manufacture of unground hob cutters (Fig. 3.) This was a serious problem for manufacturers, usually requiring special care and even specially heat treated material. The finish produced in the relieving operation on the new self-lubricated steels has virtually eliminated this difficulty.

Again, quantitative measurements are not yet available from a systematic program of tests, but there are several favorable reports from tool manufacturers, among which are the following experiences:

(Continued on p. 166)

Fig. 3 – Difference in Surface Finish on the Unground Tooth Forms Developed in Relief Machining of Two Gear Hobs Made From M-2 High Speed Steel. Left, machined from conventional M-2; right, M-2 with 0.13% sulphur. (Approximately half actual size)



Cleaning Specialists*

*[SPE'CIAL·IST—One who devotes himself to some special branch of activity.]

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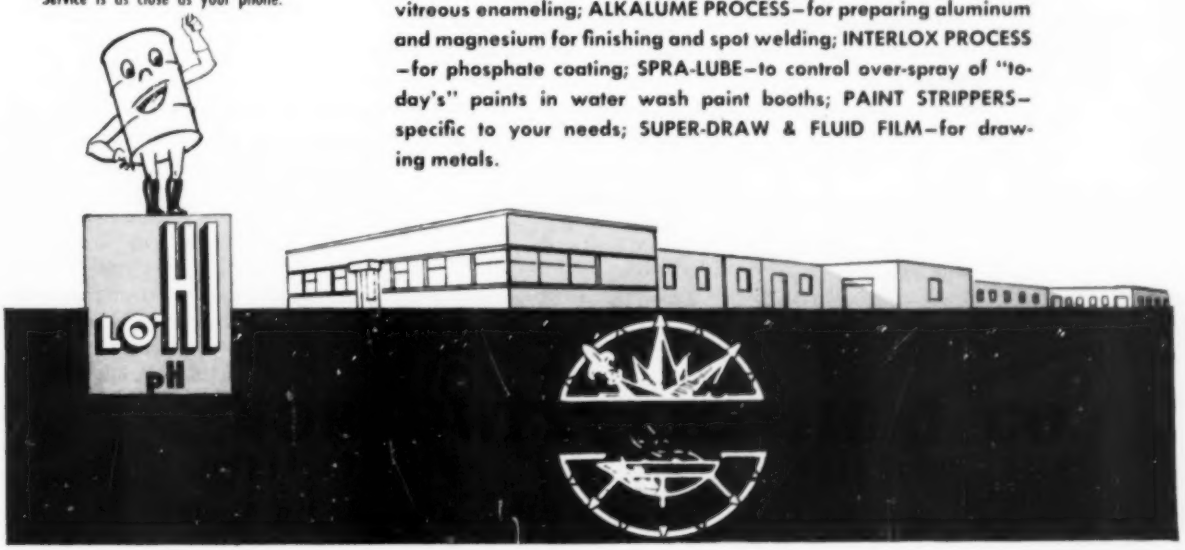

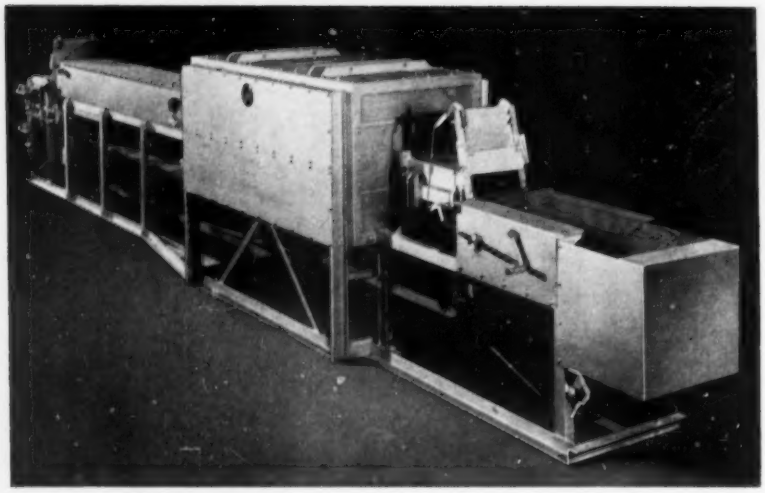

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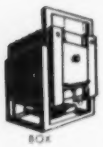
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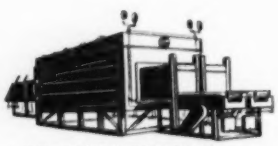
CONTINUOUS MESH BELT CONVEYOR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New Self-Lubricating High Speed Steels

(Continued from p. 164)

Side Milling Cutters – A company in New England which produces side milling cutters from 6-in. round disks, 1-in. thick, found that the turning speed on self-lubricated M-1 could be increased to 746 surface ft. per min. while the standard M-2 has a maximum permissible speed of 350 to 385 at the same depth of cut and feed. In addition, the micro-inch finish was twice as good on the self-lubricated material.

Cutting Tools – A manufacturer of cutting tools has reported that the equivalent self-lubricated high speed steel can be machined by turning, boring, and facing at a speed of 402 surface ft. per min. as compared with 226 surface ft. per min. for the conventional material, with no decrease in tool life.

Relieving Hobs – One hob per tool sharpening is considered excellent for machining regular M-2 while five hobs can be relieved with the self-lubricated M-2, before resharpening is necessary. In addition, milling cutter life has been increased at least 30% in the gashing operation on self-lubricated material.

MECHANICAL PROPERTIES

The influence of sulphur additions on impact strength of high speed steels has been studied. Though it has many limitations in practice, the impact test is probably the best common method for evaluating the dynamic loading properties of steels for cutting tools. As shown in Table I, the impact properties of M-2 high speed steel with 0.14% sulphur are practically equivalent to those of the same grade without added sulphur.

Many more mechanical tests are being conducted and the results will be available in the near future. Meanwhile, the very encouraging reports of tool life tests, in which mechanical toughness frequently plays an important role, indicate that these "self-lubricating" high speed steels, with sulphide additions carefully controlled and adequately dispersed, are just as tough and have as good mechanical properties as the conventional high speed steels.

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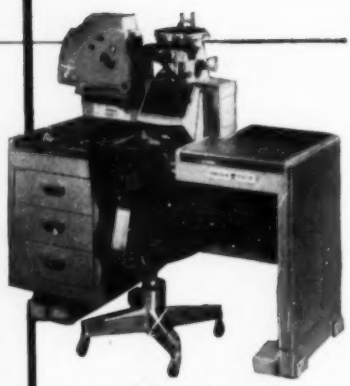

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Signed .....

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Dislocations

(Starts on p. 101)

the fixed stem can sweep out the whole face of the clock over and over again, so the section of dislocation C D rotating about the fixed section D E can sweep out the whole cross section of the crystal again and again. Every time a dislocation sweeps over the whole area of a slip plane it produces unit slip. Thus, C D, rotating about the fixed point D, can sweep out the whole cross-sectional area of a plane parallel to A B C D. A thousand revolutions will therefore produce a thousand units of slip.

Figure 6 illustrates an early stage in the process; C D has just started to rotate (in plane A B C D) about the fixed point D and has swept out the shaded area. Unit slip has occurred in this area since the dislocation started to move. Figure 7 shows the crystal after C D has made one complete revolution and swept out all of the slip plane; now the shaded area represents the area that has been swept out twice – and has slipped twice – since C D started to move. Now C D is ready to go on and sweep out the slip plane again and again.

To make C D move while D E remains fixed it is necessary to apply a stress that favors slip on the plane A B C D but not on A D E F. This could be done by holding the lower surface of the crystal fixed and shearing the crystal so that the upper surface tends to move in the direction from F to E. Such a shear favors slip on horizontal planes like A B C D but not on vertical planes like A D E F. A simple example of this stress is shown in inset between Fig. 5 and 6 on p. 106.

The clock analogy of the Frank-Read mechanism is not perfect because a dislocation is not rigid; it can change both its length and shape. Frank has shown that the rotating "arm" C D would not remain straight as it rotates; instead it would wind itself up into a spiral, with considerable increase in length. In one variation of the Frank-Read mechanism it is postulated that the dislocations already present stretch and subdivide so as to produce other dislocations (something like the production of amoebas by cell growth and subdivision). *(Continued on p. 170)*

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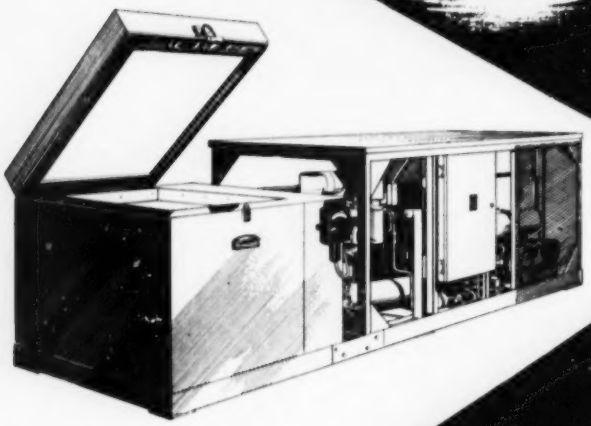

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Dislocations

(Starts on p. 101)

I am sure this sketchy discussion of dislocations has raised more questions than it has answered. For example I have not even touched on the important practical problem of work hardening. What stops the Frank-Read mechanism once it is started? Why does the stress necessary to cause slip increase as slip continues?

The detailed answers to these questions are not yet known, although we think we know the basic mechanism. As G. I. Taylor showed in his original 1933 paper, dislocations interact strongly with one another. They tend to get tangled up and lock into a stable configuration. In other words, not all of the dislocations have smooth sailing as they move through the crystal; they get tangled up with other dislocations and tie up traffic. The mutual interference seems to be particularly strong between dislocations on intersecting slip planes.

Dislocations interact not only with one another, but also with other defects. A. H. Cottrell and his coworkers at the University of Birmingham, England, have done some beautiful work on the interaction of dislocations with impurity atoms. They have thrown considerable light on the atomic mechanism of yield point and strain aging phenomena.

Dislocations are important in problems other than strength and plastic deformation. Probably the most strikingly successful application of the theory has been F. C. Frank's theory of the growth of a crystal from the vapor or dilute solution, which not only explains the mysteriously rapid growth rate at low supersaturation, but also correctly predicts the microscopic form of crystal faces on which growth will occur.

TO SUMMARIZE

Dislocation theory is just emerging from the stage of ingenious hypotheses into the stage of experimental verification. It is following — now at a rapid pace — a wellworn road that has usually led to technological advances. In one respect, however, the theory is less fortunate than certain other branches of

(Continued on p. 172)

A HUGE SAVING ON A HUGE JOB WITH dy-chek

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JAMES A. MITCHELL, *Plant Supt.*
Standard Steel Corporation, Los Angeles, Calif.

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Dislocations

(Starts on p. 101)

physics such as nuclear theory and semiconductor electronics: Centuries of empirical metallurgy have already uncovered so many practical and industrial results that physics has a longer road to travel before it reaches the frontier. However, there is no doubt that there is enough beyond the frontier to make the road well worth traveling.

One special advantage that dislocation theory has over many other branches of physics is that so much can be done without advanced physics or mathematics but with only a willingness to think clearly in simple physical pictures.

Dew Point

(Continued from p. 96)

very short. Discrepancies will also result from a see-saw control throughout a heat treating cycle. Where precision is necessary, special consideration must be given to both furnace and generator design. Fully automatic control of dew point in the furnace chamber would be highly desirable, and will doubtless be possible in the future. This problem has had top priority in our research laboratory for the past two years, and instrumentation is now under field tests.

FUTURE RESEARCH

The research laboratory of the Lindberg Engineering Co. is collecting more data on the equilibrium of dew points to many other alloy and toolsteels than listed in this article. However, the ones in the data sheet, p. 96-B, include the majority of steels used in the average heat treating shops. Studies are also being made on the shift in the carbon potential of the dew point equilibrium curves by the addition of definite percentages of a hydrocarbon enriching gas, or ammonia, or combinations of both. An infrared, continuous, automatic recording gas analyzer for methane and other hydrocarbon constituents has been employed. This program should result in some interesting equilibrium curves on the carbonitriding process that will enable the heat treater to control the carbon in the case to any desired level.

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Metallurgical Impasse in Welding Nodular Irons*

THE STATURE which nodular cast iron has gained in a comparatively short time as an exceptional engineering material is impaired to a degree by one major limitation – lack of a good structural joining or welding method. Extended research on a large number of 6x8-in. specimens of ½-in. nodular iron plate, subjected to a series of arc passes, both with and without filler metal additions, and covering such other variables as preheat, postheat treatment, welding method and type of filler rod, has indicated the direction in which the answers may lie.

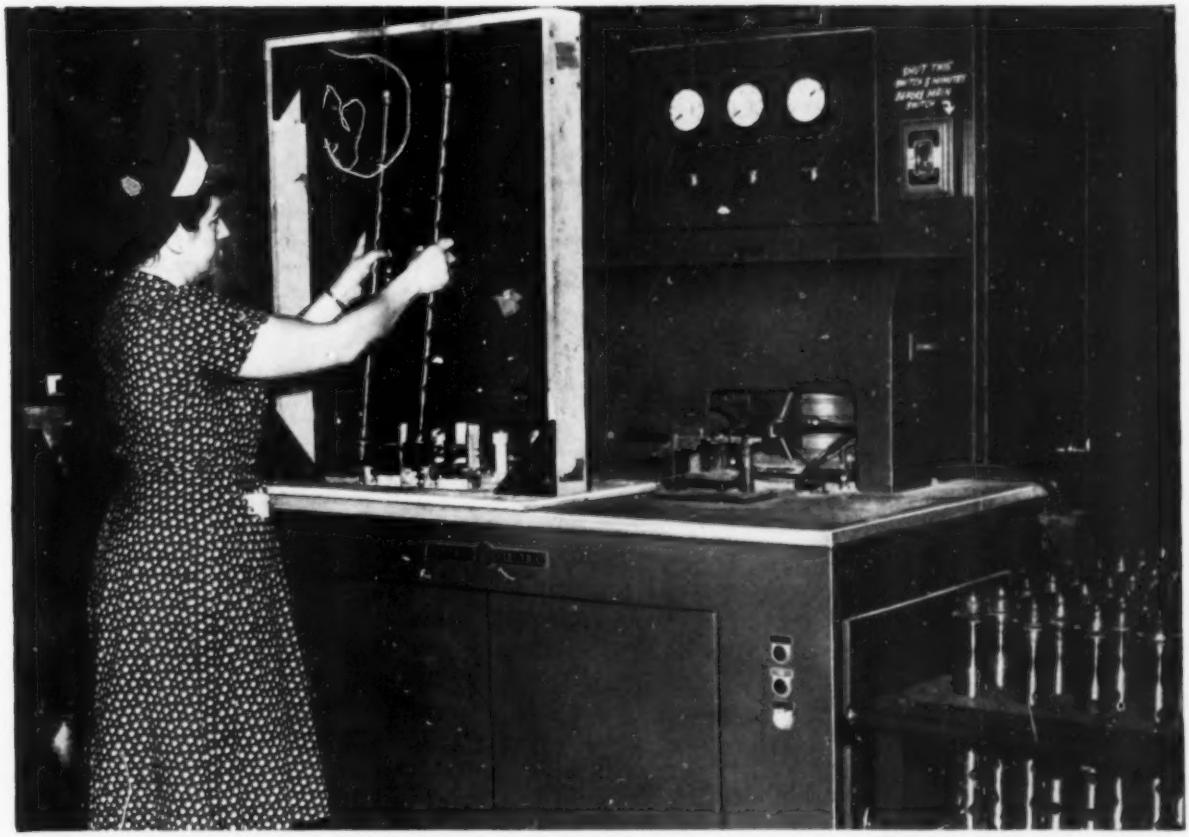
Nodular iron is essentially a low-alloy steel containing an amount of graphite equivalent to ordinary cast iron but in spherulitic or nodular form. The matrix may have different structures, according to prior heat treatment. Accordingly, a welding method will be beset with all the problems met in joining low-alloy steels, plus difficulties arising from the presence of free graphite.

Major troubles are twofold – formation of a hard, brittle continuous carbide region surrounding the weld, and the formation of a martensite network immediately adjacent to the carbide region. Martensite formation, common in ferrous welding, may be offset in part by preheating to lessen the rate of cooling through the critical range, or by postheating to temper the martensite constituent.

Carbides, however, present more complex considerations. The carbide region results from rapid diffusion of carbon from graphite nodules, resulting in a lowering of the melting point of the matrix, causing fusion to start around each nodule. Liquid thus formed corresponds roughly to liquid cast iron, which freezes as white iron due to the relatively high cooling rates of welding heat cycles. Preheating is of no help; to obtain a freezing and subsequent cooling rate slow enough to permit graphitization, the preheat temperature would need to approach the melting point, which is not feasible commercially.

(Continued on p. 176)

*Digest of "Welding Metallurgy of Nodular Cast Iron", by Edward E. Hucke and Harry Udin, *Welding Research Supplement*, August 1953, p. 378-s to 385-s.



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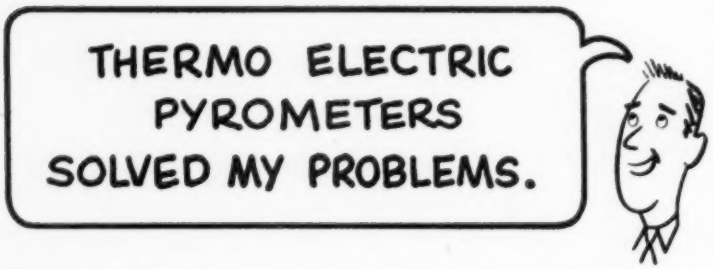

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Welding Nodular Irons

(Continued from p. 174)

Use of a ferritizing postheat treatment likewise is unsatisfactory, because the carbide region graphitizes in very small nodules which have a deleterious effect. Furthermore, such treatments must be carried out at temperatures of around 1675° F. for a substantial period of time, thus raising costs and limiting the size of weldments.

In the studies of microstructures resulting from various sequences of arc passes, four rather clearly defined regions or zones have been observed. They are briefly as follows:

Region 1 – That portion of the base plate not affected by the arc pass and showing the nodular graphitic structure in a ferrite matrix.

Region 2 – An area where peak temperature was not reached and no liquid was ever present. Structure consists of nodular graphite surrounded by a complex gradation of austenite transformation products.

Region 3 – Areas where liquid existed around each nodule but where liquid interfaces from neighboring nodules had not met. High-carbon liquid surrounding each nodule solidified as primary carbide and eutectic, while the austenite surrounding this liquid transformed to martensite. Two slightly different structures are noted, dependent upon cooling rate and metal composition. With slow cooling rates and a composition favoring graphitization, the carbide in a narrow ring surrounding each nodule has deposited graphite on the nodule, leaving a ferrite ring. With faster cooling, the graphitization proceeded as before, except that the region depleted in carbon by graphitization never reached a low enough carbon value to prevent it from transforming to martensite at lower temperatures.

Region 4 – An area of complete fusion where liquid interfaces have joined. Structure is that of a hypo or hypereutectic white iron, according to the base plate composition.

With the addition of filler metal, a fifth region – fused filler metal – makes its appearance. If, in applying filler metal, the base plate melts, then all of the previously mentioned four regions must be present.

Region 4 is the most detrimental

(Continued on p. 178)

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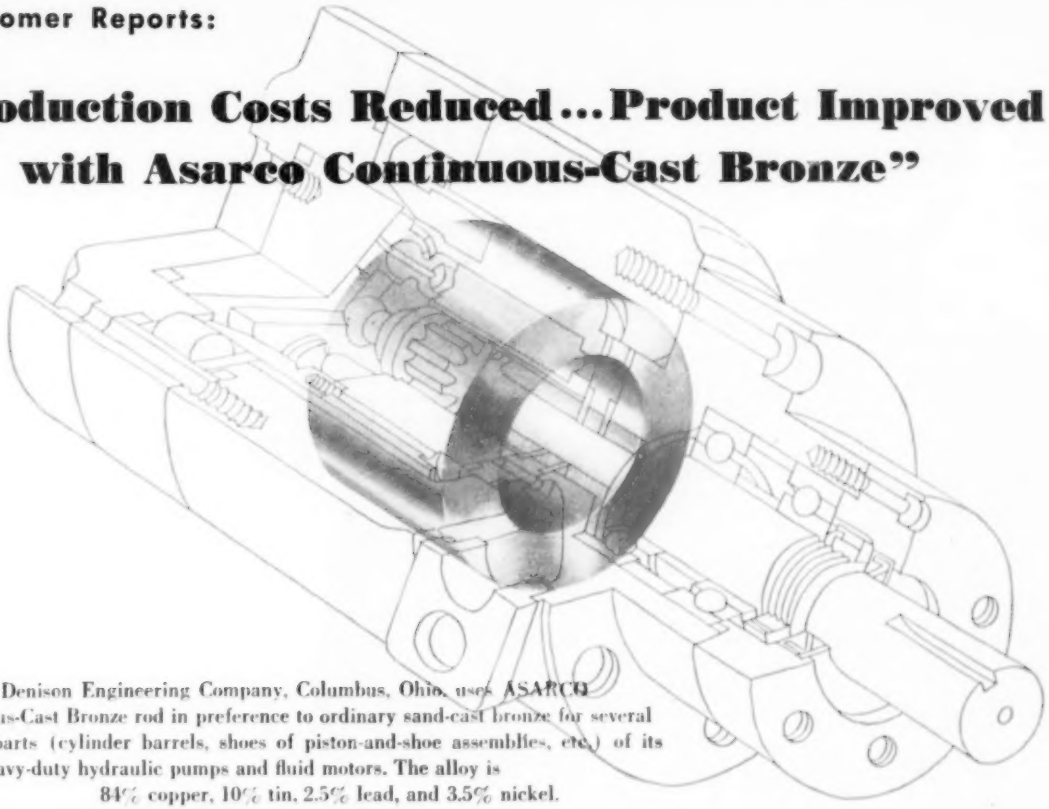

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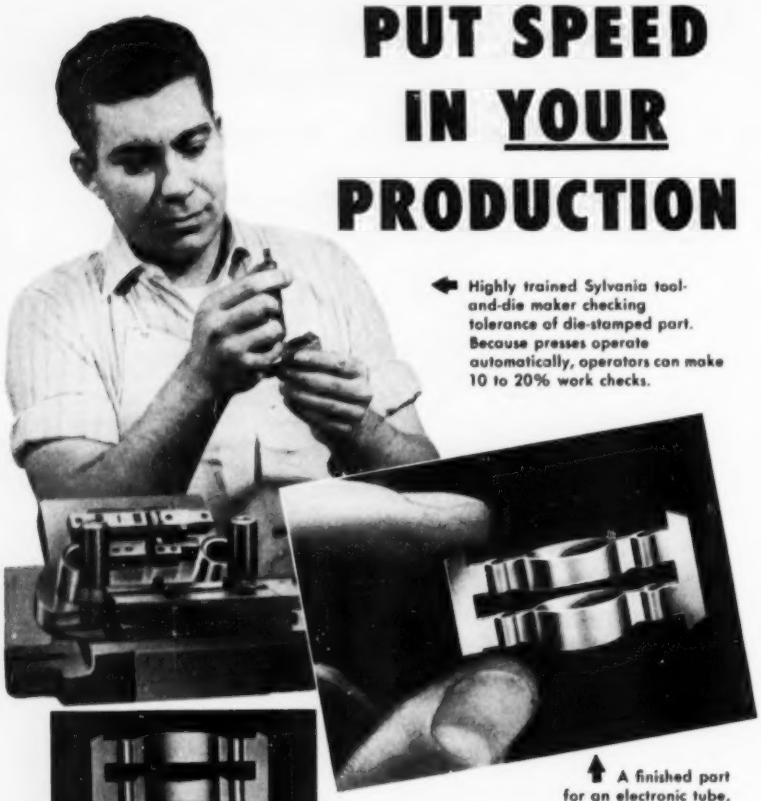

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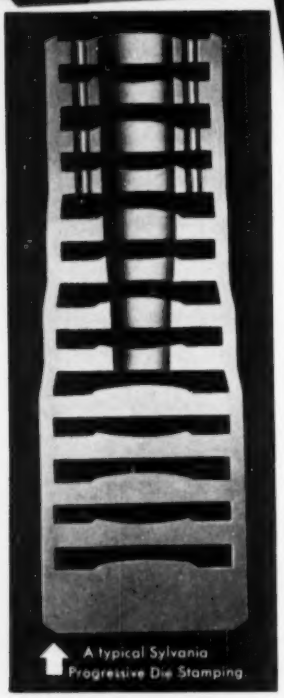

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Welding Nodular Irons

(Continued from p. 176)

to the finished weld, because of its hard, continuous and brittle carbide. Region 3, while containing carbide, may not impair weld strength because it is not necessarily continuous.

All joints made in the tests with filler metal could be fractured easily with a hammer and none was machinable to the extent that it could be sectioned with a hacksaw. Metallographic examinations showed fractures to be mostly in the continuous carbide region 4. In one specimen this brittle region was absent, since it was actually a brazed joint (phosphor bronze filler metal).

In summary, it appears that, metallurgically, the ultimate solution rests with a brazing process, using filler metals which melt below the eutectic temperatures of commercial nodular irons (about 2300° F.). However, such metals must have comparable strength and ductility to that of the nodular iron, and presumably must not be costly. Aluminum bronze appears to qualify on every count, except perhaps cost. A. H. ALLEN

Intergranular Brittleness*

THE EFFECT of oxygen additions to pure iron melts was studied by means of tensile and Charpy impact tests for a range between −320 to 390° F. The work originated from an observation which indicated that when purified iron contained over 0.003% oxygen, the brittle characteristics were greatly increased.

Twelve alloys were prepared in an induction furnace in 25-lb. heats. Selected Swedish iron was first melted in air and deoxidized with hydrogen; the hydrogen was then removed and the required oxygen content was added in the form of iron oxide to the melt. In an attempt to remove the small amount of nitrogen (in every instance under 0.004%) the melt was held in a vacuum for 1 hr. before casting. By this practice, heats were made containing oxygen in amounts varying from 0.0008% to a maximum of

(Continued on p. 180)

*Digest of "Intergranular Brittleness in Iron-Oxygen Alloys", by W. P. Rees and B. E. Hopkins; *Journal* of the Iron and Steel Institute, Vol. 172, December 1952, p. 403-409.

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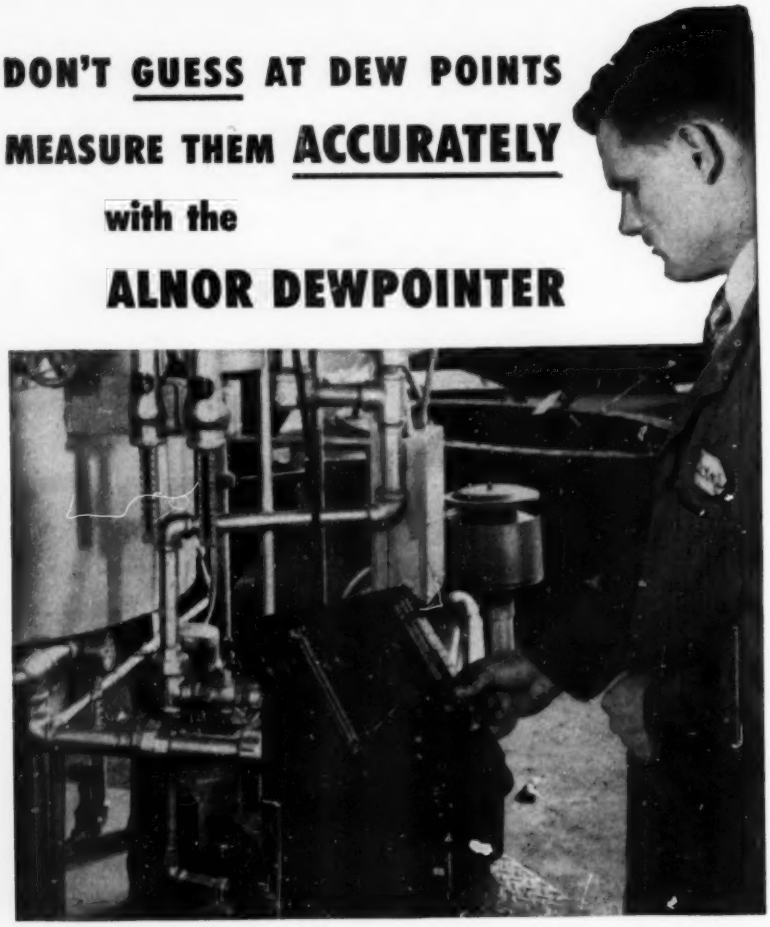

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Intergranular Brittleness

(Continued from p. 178)

0.27%. The ingots were reheated to 2010° F. and rolled to ⅝-in. diameter bars for the physical tests. Prior to testing, the bars were normalized by heating for about 10 min. at 1740° F. and cooling in air.

Tensile tests were conducted at 390, 85, −100 and −320° F.; test pieces were 0.283 in. in diameter with a 1-in. gage length. The results of tensile tests are summarized in a series of charts for each of the four testing temperatures.

None of the alloys exhibited a definite yield point at 390° F. At room temperature there was a marked yield point in alloys containing small amounts of oxygen, but with high oxygen contents the yield point became very indefinite. At −100° F. a slight indication of yield point was found at all oxygen levels except one. The elongation and reduction of area decreased steadily with increased oxygen contents at room temperature and at 390° F.

At −100° F. the ductility exhibited a very sharp drop from 90% to less than 50% at a very slight increase in oxygen content above 0.003%. Tests at −320° F. showed no yield strength and practically no elongation or reduction of area. At this temperature the tensile strength dropped sharply when the oxygen content rose above 0.003%. The amount of this decrease in tensile strength was from 105,000 psi. at the lowest oxygen level to about 49,000 psi. at 0.003% oxygen. All alloys having greater than 0.003% oxygen which were tested at this temperature showed an extremely brittle fracture with little change in strength.

Charpy impact tests prepared with an Izod V-notch were carried out over a temperature range covering the tough-to-brittle transition for each melt. A sharp change from tough-to-brittle behavior was observed in the single-phase iron alloys. When the oxygen content of the metal increased above 0.011%, the transition from a ductile to a brittle fracture was more gradual. The effect of the increase in oxygen content was very definite and the transition temperature of each melt at which a brittle fracture appeared was steadily raised as the oxygen content

(Continued on p. 182)

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Intergranular Brittleness

(Continued from p. 180)

increased. The heat with 0.001% oxygen showed a sharp transition temperature at about 23° F.; the one with 0.0046% oxygen at a transition temperature of 212° F.; the heat with 0.011% oxygen at 345° F.; with 0.057% oxygen at a transition temperature of approximately 660° F. The melt with the highest oxygen content, 0.27%, showed no definite transition temperature and exhibited very low impact tests, even at temperatures as high as 1110° F. The effect of increase of the oxygen content on the transition temperature in the single-phase iron alloys is very definite and significant.

For the four melts containing less than 0.002% oxygen, the low-temperature fractures of the brittle samples were of the cleavage type. Samples containing more than 0.0037% oxygen and having a transition temperature of 60° F. developed fractures which were partly intergranular and partly cleavage. As the oxygen content increased above this level, the transition temperature continued to rise as the proportion of intergranular fracture in the broken pieces increased.

Examination of the broken test pieces was made to determine the presence and amount of FeO and also the character of the structure at the fractured surface. As oxygen content increased above 0.007%, there was a corresponding increase in the number of FeO particles in the specimens. When the oxygen content was below 0.004%, no oxide particles were observed; consequently, the authors assume a solubility of oxygen in iron of about 0.003%.

The fracture test pieces exhibited marked Neumann bands and there was some relationship between their occurrence and the location of the oxide particles in the high-oxygen heats. Grain-boundary cracks were also apparent in all of the heats containing high amounts of oxygen, particularly in the impact test pieces. The paper contains numerous micrographs exhibiting these features of the structure.

Under the conditions employed in this investigation, the authors conclude that the addition of over 0.003% oxygen to iron increases the

(Continued on p. 184)

what's new

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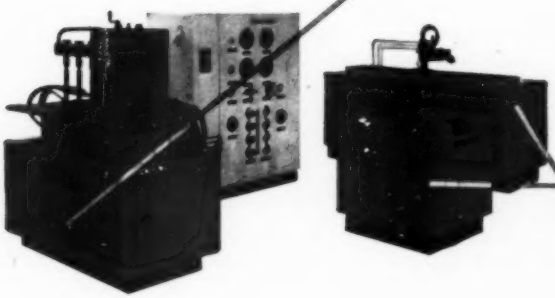
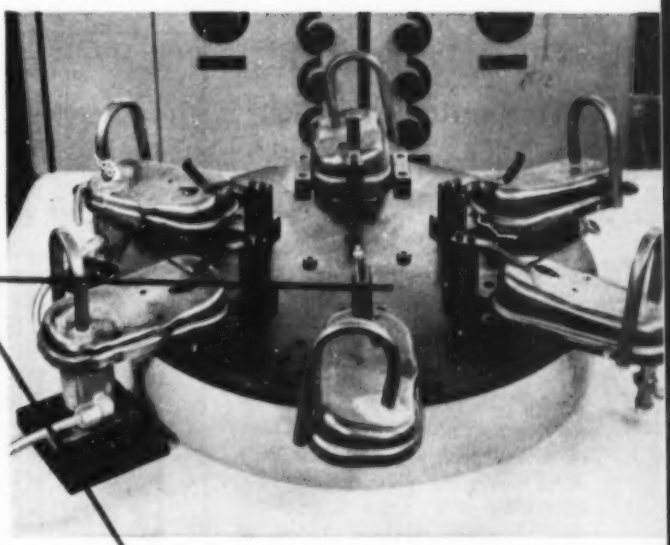
Top: New Flamatic combination hardening unit for shafts, spindles, etc., up to 18" long and 1⅞" OD. Shafts rotate, flame heads move vertically. Preset dwell and infinitely variable travel and quenching rates provided. Six 12" long shafts as illustrated are hardened in 120 seconds, floor to floor.





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Intergranular Brittleness

(Continued from p. 182)

tendency to brittle fracture and also promotes intergranular brittleness at the higher oxygen levels. The influence of oxygen on the impact transition temperature was most marked at oxygen contents between 0.003% and 0.011%. It is concluded that the rise in impact transition temperature with increased oxygen content was largely due to a decrease in brittle fracture strength. Microscopic examination showed no intergranular phase to explain the marked grain boundary weakness caused by high oxygen contents.

E. C. WRIGHT

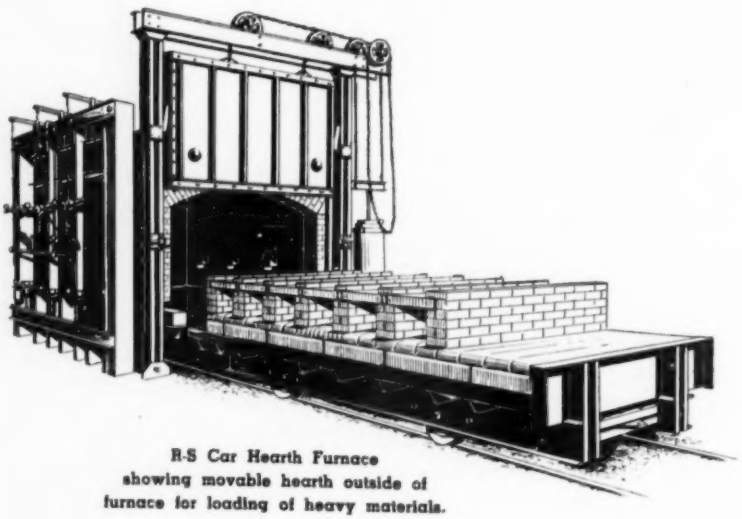
Basic Diagrams of Composition Vs. High-Temperature Strength*

RECENTLY, the Russian investigators Shishken, Bochvar, Zakharov and Kornilov have been studying the effect of composition and structure on the resistance of alloys to prolonged stressing at high temperatures. The centrifugal method of testing (described in *Metal Progress* for October 1951, p. 194) that Kornilov has been using for the past seven years has permitted the accumulation of a large volume of experimental data. These data indicate that there are three types of diagrams for composition versus high-temperature strength: continuous solid-solution, with or without the formation of a compound; partial solid-solution, with appreciable solubility and with the extent of solubility changing with temperature; and that with very little or no solid solubility. These are shown in Fig. 1, in which any of several measures of high-temperature strength could be plotted; therefore a representative value is shown by the broken line.

In the diagram of the first type, two variations of high-temperature strength with temperature are possible: (*a*) At temperatures above the region of existence of a compound the curve passes through a flat maximum; the silver-gold, copper-nickel, and possibly the tungsten-molybdenum, titanium-zirconium, and other systems show this behavior. If the melting points of the two metals are markedly different, the character of the curve may change and show greater high-temperature strengths for the solid solutions having the higher melting temperatures. (*b*) At temperatures at which a compound forms, the curve of high-temperature strength shows a sharp maximum, whereas short-time properties (such as hardness or yield strength) have a minimum at this composition. The maximum is explained by the difference in the character of a long-time diffusion process in a compound compared to that in a composition having an excess of either of the components. Alloy systems corresponding to this type of diagram are magnesium-cadmium, iron-nickel, and nickel-manganese in which the maximum strength values occur at the compounds MgCd, Ni_3Fe and Ni_3Mn. Other systems are Au-Cu, Fe-Cr, Fe-V, Fe-Pt and Fe-Pd.

In diagrams of the second type, high-temperature strength also increases with increase in concentration of the solid solution. However, there is a jump in the vicinity of the saturation limit of the solid solution, both for a pure metal and for a com-

*Digest of "Basic Types of Diagrams of Composition Versus High-Temperature Strength in Metallic Systems", by I. I. Kornilov, *Doklady Akademii Nauk SSSR*, Vol. 86, 1952, p. 721-724.



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pound. Systems of this type are Al-Mg, Ni-Cr, Ni-Al, Ni-W, Ni-Cr-Al, Ni-Cr-Cb, Ni-Cr-Ti, Ni-Cr-Al-Cb, Ni-Cr-W-Cb, Ni-Cr-W-Ti, and many other combinations.

In diagrams of the third type the effect of solid-solution formation is negligible; therefore the two phases form a mechanical mixture and the high-temperature strength varies uniformly across the diagram. Systems in this category are Cu-Cr, Cu-Ca, and Mg-Cl.

It is pointed out that these types of diagrams are valid only for certain testing temperatures, and they will change as the solidus temperature is approached. In general, compositions corresponding to solid solutions have better high-temperature strengths at these high temperatures than heterogeneous alloys having lower solidus temperatures.

A. G. Guy

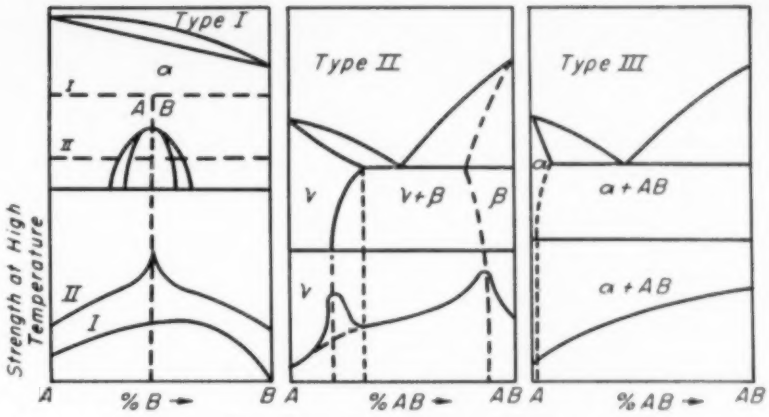

Fig. 1 – The Three Basic Types of Diagrams of Composition Versus High-Temperature Strength

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Properties of Aluminum Bearings*

Durability and long life of automotive engine bearing materials rest on a combination of properties including antiscoring qualities, fatigue resistance, bond, embeddability, conformability, corrosion resistance and load-carrying ability. The steady increases in engine speeds, compression ratios and horsepower over the past 20 years frequently have been deterred by inadequate bearing materials, especially for the connecting rod and main bearings.

Conventional thick babbitt-lined bearings years ago began to develop failures due to fatiguing. Improvements took the form of a porous metal matrix bonded to the steel backing and then covered with a thin cast lead-base babbitt layer. By reducing babbitt thickness to a thin film, fatigue resistance was increased adequately, but conformability and enbeddability suffered in heavy-duty applications.

Aluminum as an engine bearing material dates back many years. Principal drawback to its general acceptance was the difficulty of bonding it tightly to steel, and the metal's high coefficient of thermal ex-

*Digest of "Properties and Production of Aluminum Bearings", by Arthur B. Shaw, *Engineering Journal* (General Motors Corp.), Vol. 1, June-July 1953, p. 49.

pansion which resulted in seizing and welding to shafts.

Lengthy study by the research laboratories of General Motors Corp. finally revealed a new aluminum bearing alloy and a modified bonding method which avoided any brittle iron-aluminum alloy at the bonding line. The aluminum layer was kept relatively thin to control expansion. However, a babbitt overlay was considered advisable to avoid excessive scoring.

The next problem was that of electrodepositing a thin layer of babbitt on the aluminum. Upshot was the perfection of a method for codepositing a lead-tin alloy with sufficient tin to avoid corrosion by lubricants, and with copper for added strength and load-carrying ability.

When the technique had been perfected, sample bearings were run for long periods of time in test engines to confirm their anticipated performance. Endurance tests in a truck engine, for example, showed a life for the steel-aluminum-babbitt bearings 7½ times that of conventional babbitt types. Load-carrying ability was checked at four to six times that of babbitt.

Load tests were made by reducing a connecting rod bearing length to ⅝ in. through counterboring the ends, giving an L:D ratio of 1 to 4, and then running for 100 hr. at 4300 rpm., full throttle. No failures resulted in this test.

To increase pressures still further, a standard-length aluminum bearing was grooved at the center to leave a ¼-in. land at each end, resulting in two bearing lands, each having an L:D ratio of 1 to 10. This was estimated to increase actual pressures by 500%. The bearings still performed satisfactorily.

Encouraged by these tests, the Moraine Products Div. of General Motors is now setting up production facilities to turn out the new bearings in the necessary volume for engine requirements of the Corporation's other divisions. They are completely interchangeable with babbitt-lined bearings and run equally well on oil-hardened shafts.

A. H. Allen

Six Sub-Zero industrial freezers are currently in use at A. V. Roe. High speed steel cutting tools are chilled to −120°F as part of the heat treating process to produce greater hardness and strength and improved ductility. All types of gauges—snap, plug and profile—are Sub-Zeroed for stability to eliminate growth and distortion.

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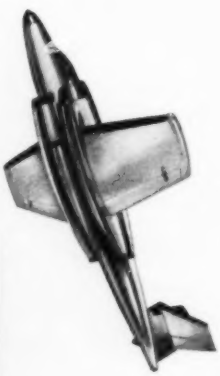

reports A.V. ROE, Canada jet engine maker

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Quality Control in the Production of Copper and Its Alloys*

In Great Britain, fire refined (rather than electrolytic) copper is normally utilized for the production of copper shapes intended for fabrication. Rotary or tilting furnaces up to 20 tons capacity are used, as well as reverberatory furnaces, such as the 200-ton basic-lined unit employed at the Enfield Copper Refining Co. Ltd., in which firm the author is a director.

The 200-ton furnace is usually charged with a blend of Rhodesian blister and high-grade scrap resulting from sorting and sampling procedures. Heavy oil (containing up to 2.75% S) is used for melting and light oil (0.5% S maximum) after blowing and sulphur removal. Draft gages and CO_2 recorders are employed to obtain the combustion conditions given in the table on p. 188.

After the charge is off bottom, blowing is begun with 20 lb. of air

(Continued on p. 188)

*Digest of "The Control of Quality in Melting and Casting Copper and High-Conductivity Copper-Base Alloys", by J. Sykes, *Journal* of the Institute of Metals, Vol. 81, March 1953, p. 351-363.

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Tool Characteristics – Wear Resistance

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Quality Control in Production of Copper and Its Alloys

(Continued from p. 186)

for sulphur removal, and is continued until the bath reaches 0.9% O_2. Lead, if present, is removed by slagging with silica sand. If arsenic or antimony must be eliminated, treatments with soda ash and lime are begun at 0.75% O_2, and a temperature of 2200° F. These are blown under the surface from a blow tank using 90 lb. air, and a pole for stirring. After each addition the bath is skimmed and sampled, and the degree of elimination followed by spectrographic estimation until a value of less than 0.002% As is reached.

Combustion Conditions in Copper Refining*

Process	Time	Mean Flue-Gas Temp.	Oil Used, Gal. per Hr.†	Mean CO_2 Content
Charging	6 hr.	1770° F.	‡	15%
Melting	6	1900	300	15
Oxidizing	4	1850	180	10
Poling	3	1850-1900	50	8
Casting	5	1090	30-40	5

*For a complete refining cycle of a 175-ton-capacity oil-fired furnace.

†Imperial gallons; 1 imp. gal. = 1.2 U.S. gal.

‡Rises from 50 to 300 in 1st hour, then constant.

The final test for arsenic (and also for antimony) removal is made by dipping out a small quantity of molten metal in a hot graphite crucible, reducing to pitch, and casting, rolling and drawing the sample to wire for a conductivity determination to insure a minimum of 100%. Usually, it is not necessary to remove arsenic much below 0.0015%.

Soda ash is also effective in removing tin, particularly in the presence of sodium nitrate, but these slags are exceedingly corrosive to furnace brickwork. Selenium is not removed under oxidizing conditions, but an experimental run using soda ash and charcoal with a reducing atmosphere in the furnace eliminated 70 to 80% of the selenium content of a charge containing about 0.10% Se.

After final skimming, the bath is covered with about a ton of low-sulphur coke, and poling is commenced under a slightly reducing flame. Progress of the reducing action is followed by button samples taken with a say-ladle. Charcoal additions are used instead of coke to prevent sulphur contamination after the oxygen content has reached 0.07%. The final pitch is judged by casting 9x4x4-in. samples which show a crown set when the bath is ready for casting.

Thermocouples and optical pyrometers are used during the refining and casting cycles to prevent undesirable fluctuations. The casting of 250-lb. wirebars is carried out at 2030 to 2050° F. (ladle to mold). Ladles and launders are lined with 49% washed sand, 49% portland cement and 2% fireclay. Ladle lips are washed with hard-setting high-alumina cement. The ladle channels

(Continued on p. 190)

YOUNG BROTHERS OVENS
FOR HEAT TREATING

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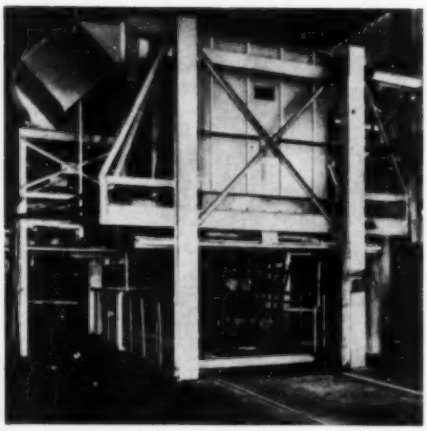

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13/16 thru 1"	x .015 to and including .035
1" thru 1 1/4	x .020 to and including .035
1 1/4 thru 1 1/8	x .025 to and including .035
1 1/8 thru 1 1/4	x .032 to and including .035

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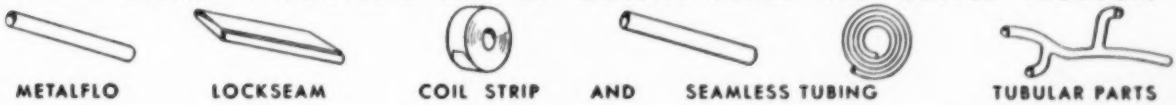

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how CHACE THERMOSTATIC BIMETAL GUARDS AGAINST FIRES IN FireStaT

A Product of
The FireStaT Co.
Wheaton, Ill.

One of the simplest and most economical, completely effective automatic fire detection units is the FireStaT, actuated by two Chace Thermostatic Bimetal elements. Because of its low cost, many units can be used to protect a wide area economically, and as an open circuit is used there is no cost of operation.

A unit is located in an area to be guarded and connected in series with a power supply of 24 volts or less, and a warning device such as a light or bell. Where higher powered warning devices are indicated, or where a long line is required, the FireStaT is connected to a relay to step up the power.

The two Chace Thermostatic Bimetal elements give double protection. At an increase in ambient temperature the elements deflect toward each other. As the tip of either element touches the other, the circuit is closed. Increase in temperature brings both tips more forcibly in contact and in a sliding action, giving a positive double contact. Thus, a dependable warning signal is assured. FireStaTs come in standard models which give warnings at 140, 190, or 250 degrees F.

This illustrates but one of the many applications of Chace Thermostatic Bimetal as the actuating element for temperature responsive devices. If your product responds to, indicates or controls temperature changes, actuate it with dependable Chace Thermostatic Bimetal. Write today for our new 36-page booklet, "Successful Applications of Chace Thermostatic Bimetal", containing condensed engineering data and information.

IT BENDS WITH THE HEAT
W. M. CHACE CO.
Thermostatic Bimetal
1626 BEARD AVE., DETROIT 9, MICH.

Quality Control in the Production of Copper

(Continued from p. 188)

are 2-in. squares, open at the top and carefully dressed to prevent splashing. Methods for testing the bone ash mold dressing are given.

Casting defects in horizontal castings and their causes are:

1. Moisture holes—moisture from surface defects in molds.
2. Oil holes—extraneous oily spot on mold.
3. Bone ash inclusions—bone ash too heavy or high mold temperature.
4. Cracks—rough molds, high metal temperature, poor dressing.
5. Sand inclusions—improper refractories in ladles, etc.
6. High set—too much poling or high sulphur content.
7. Dimensional defects—mold pocket improperly filled.
8. Laps—cold sets or splashes not turned in by fisher.
9. Heat holes—metal temperature too high.
10. Rolled or sloppy edges—fast pouring, jerky finish, vibration.

While vertical cakes may be wheel cast, the use of racks for vertical molds, fed by 5-ton portable furnaces which are filled from the reverberatory, enables the production of both horizontal and vertical shapes from the same heat. Vertically cast cakes are produced from solid copper molds which have drilled water passages. For a 1000-lb. cake, water at 190 to 205° F. is circulated at a rate of 150 gal. per min. at a pressure of 60 lb. Pelican ladles are used to "float" the stream and avoid splash. Billets and vertical wirebars are poured by means of a funnel. Funnel orifices are 9/16 in. for a 4-in. square bar, and ⅝ in. for a 4½-in. diameter billet. Pouring rates are 400 lb. per min. at 2010 to 2030° F. for wheel casting and 2030 to 2050° F. for rack casting. Billets (4½ in. square) are poured within 72 to 90 sec. at 2085 to 2090° F.

Details are also given for the alloying and casting of phosphorus-deoxidized copper, silver-bearing copper, tellurium copper and cadmium copper. In addition, much of the equipment is illustrated, and most of the control methods, both physical and chemical, are either given in detail or outlined.

J. S. Smart, Jr.

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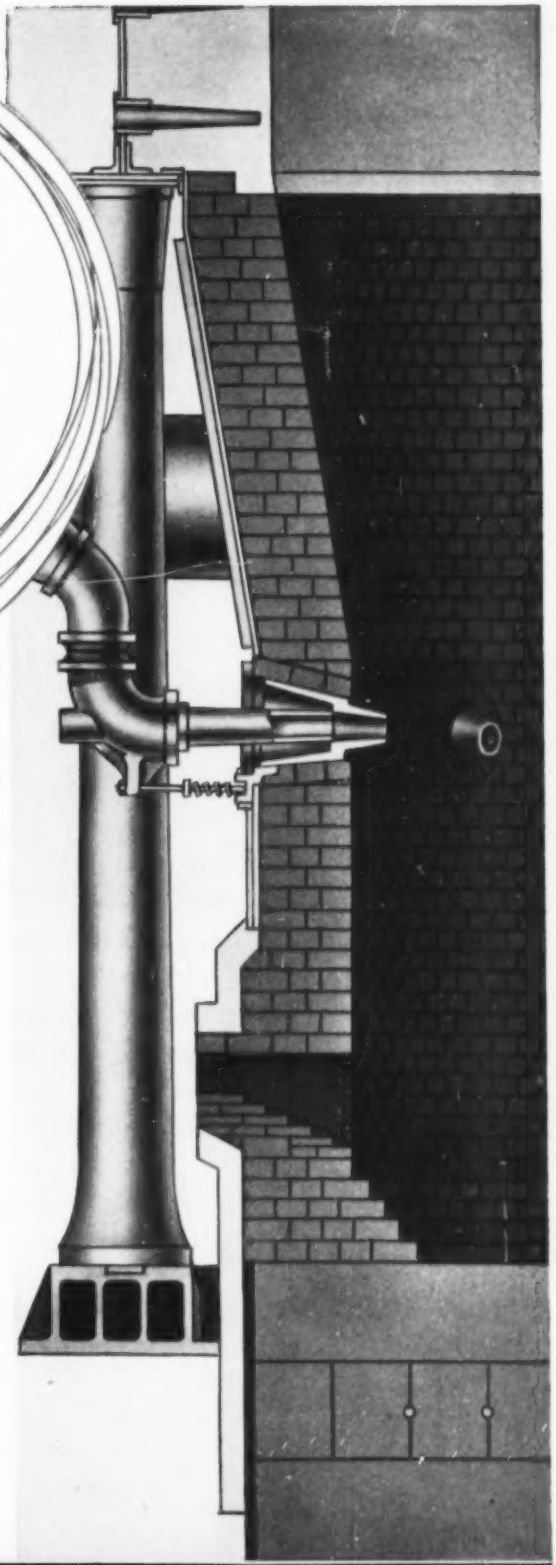

Record operating economies — so outstandingly established by "National" carbon in blast furnace hearths—*needn't stop there!* Now you can get the same advantages — longer life, lower maintenance, smoother operation—with carbon linings in blast furnace walls, in tuyere and in bosch sections.

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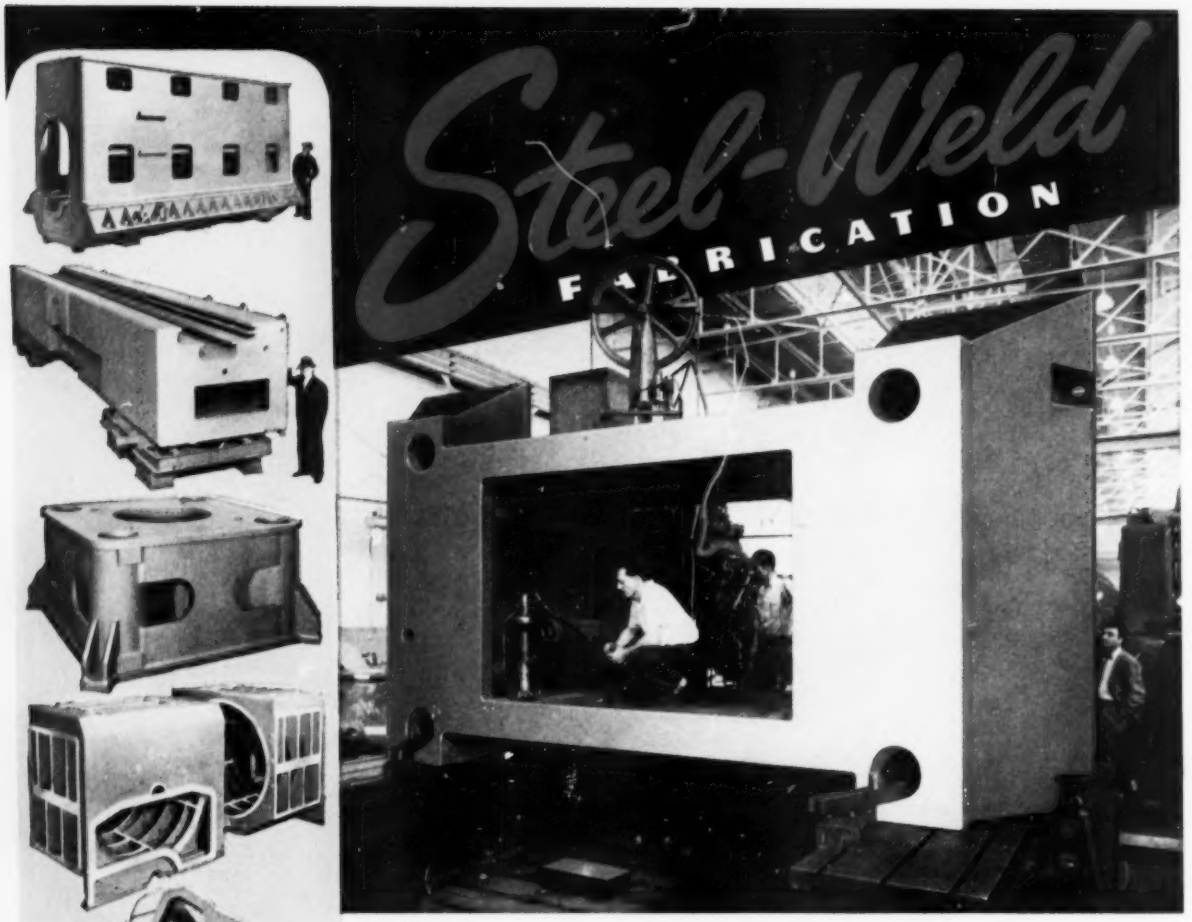

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Ultrasonic Equipment for Thickness Measurement*

THE ULTRASONIC measurement of the thickness of tubes and plates is based upon the principle of ultrasonic resonance. It is a nondestructive test easily applied to parts where access from only one side is possible. High-precision measurement (using the "Audigage Micrometer") is limited to materials which conduct ultrasonic waves at frequencies of 0.5 to 5 megacycles. These are cast metals of small grain size, most rolled or forged metals, glass, and some plastics such as lucite. The accuracy obtained is within ½% of actual dimensions.

High-frequency compressional waves are transmitted into the material being tested, through a thin layer of a suitable couplant, such as water, oil, or glycerine. At certain frequencies a standing wave is set up in the part under test, as indicated by headphones, meter, or oscilloscope. The lowest or fundamental frequency at which this condition occurs is given by the formula:

$$F = \frac{v/2}{t} = \frac{c}{t}$$

where F is the frequency, v the velocity, t the thickness. Similar indications are obtained at multiples of the fundamental frequency, such as 2F, 3F, and 4F. These multiples of the fundamental frequency, the harmonics, are equally spaced, and the fundamental can be determined by subtracting two adjoining harmonics.

Commercial equipment normally uses one of two methods. The oscilloscope instrument usually operates on the fundamental frequency. Hand-tuned equipment, such as the "Audigage" thickness tester, usually operates on harmonics. Measurements within 2% of the actual wall thickness are easily obtained. When greater precision was needed, of the order of ½%, the author obtained this by making minor variations in the Audigage tester, and using careful testing technique.

The sharp signals and good reproduction required for precise measurements could not be achieved with the fundamental frequency alone, while the method of taking the difference between two harmonics was too inaccurate, since the errors in both readings were introduced.

A more accurate instrument called the Audigage Micrometer was developed employing a circuit that is practically free of frequency drift.

Frequencies were selected on one of the harmonics and scales calibrated directly in thickness or percentage. By selecting the crystal, frequency range, scales, and other components for maximum performance, sharper indications were obtained than with standard equipment. The crystal frequency was chosen close to the test frequency.

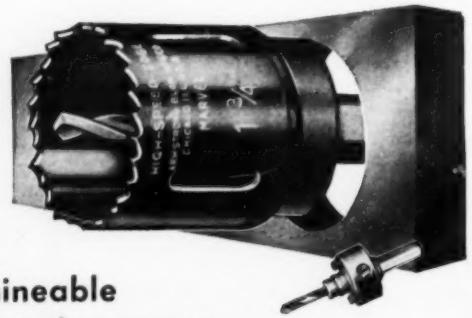
Small temperature variations did not affect the measurements. The size of the part was not critical; tests made on small samples gave thickness values accurate for large structures. However, the width of the test specimen always had to exceed the thickness. Sharp indications were obtained only if the thickness was reasonably uniform. Slight tapers were tolerated, but parts with severe taper could not be tested accurately.

The degree of coupling between

(Continued on p. 196)

*Digest of "Ultrasonic Equipment for High-Precision Thickness Measurement", by Peter K. Bloch, *Nondestructive Testing*, Vol. 11, May 1953, p. 21-23.

Cut...



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... thru any machineable material up to 1⅛ inches thick!

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MARVEL High-Speed-Edge Hole Saws have strength to withstand the terrific peripheral strains of heavy duty operation in lathes, drill presses or portable power tools. They have a high speed steel cutting edge which is electrically welded to a tough, alloy steel body, high speed steel pilot drills, heavy hexagonal shanked arbors and sufficient set for deep drilling. They are self-aligning, as the larger diameter saws float on their arbors and are driven by double drive pins. They will saw round holes accurately in any machineable material.

MARVEL High Speed-Edge Hole Saws come in 35 sizes, from ⅜" to 4½". They are carried in stock by leading industrial distributors.

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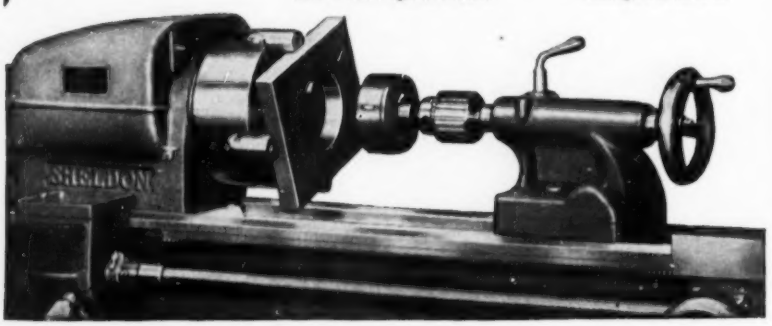

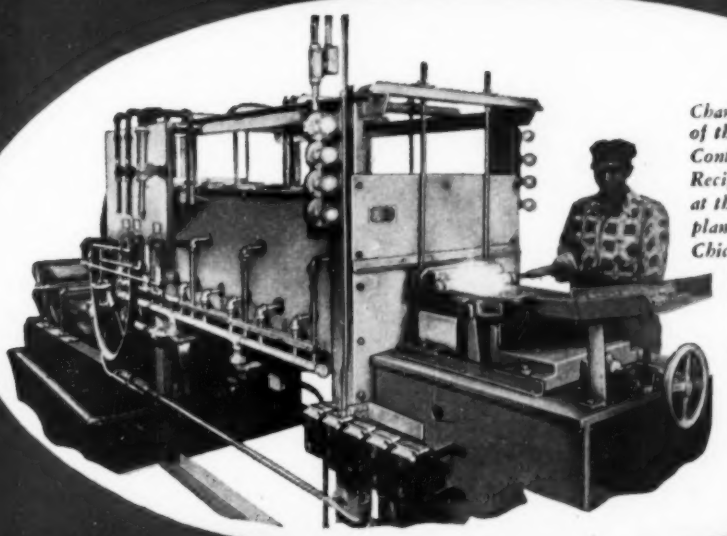

Charging end of the No. 166 Continuous Reciprocating Furnace at the Bellwood, Ill., plant of Chicago Screw Company. The furnace, made by American Gas Furnace Co., is equipped with a cast Chromax muffle.

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in shaker hearth furnace

CHICAGO SCREW COMPANY runs this Reciprocating Furnace 24 hours a day, at temperatures from 1550°F. to 1650°F., in an atmosphere of ammonia and carburizing gases, for case-hardening their high quality screws and other threaded fasteners.

In addition to the mechanical stress (up to 60 reciprocating movements per minute) the furnace muffle has to stand considerable thermal shock—for the top of the muffle is hot, while the bottom is continually quenched by cold work pouring in at the rate of 200 lbs. an hour. Under these severe operating conditions it's mighty good news to Chicago Screw that the replacement rate on their muffles is so low. They give full credit to Chromax, the alloy which combines great strength with resistance to high temperatures—also to strict observance of the furnace manufacturer's instructions.

For over 35 years, we have been helping manufacturers meet their heat-treating requirements, to speed operations, maintain quality standards, and cut costs. In most applications Nichrome gives an even lower heat-hour cost than Chromax. But when defense restrictions make Nichrome impossible to obtain, Chromax does a highly economical job, as it did here. Let us know your specific needs; we will be glad to make recommendations and serve you to the best of our ability.

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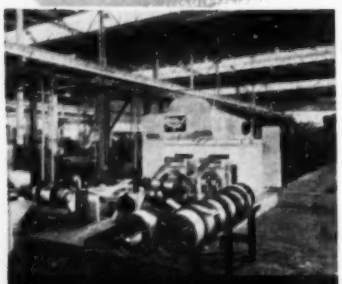

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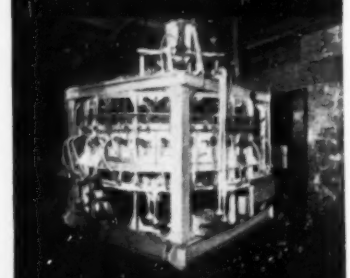
Continental Special Automatic Pig Molding Machine complete with automatic charging, melting, and pouring.

Continental Automatic Production Line operating from raw materials to completely finished and packed product. This production line consists of fifteen integrated, synchronized, special automatic machines.



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Ultrasonic Equipment for Thickness Measurement

(Continued from p. 194)

the crystal and work influenced the readings. Tests were made using 3S-H14 aluminum sheets. Reproducible results were realized by duplicating the degree of coupling and using harmonics whenever possible.

The accuracy of ultrasonic resonance thickness measurements has been improved by expanding the frequency scales, so that the scale can be read more accurately, choosing frequencies which give maximum signal sharpness, and preventing variations in coupling. The resulting increase in accuracy has made it possible to detect very small variations in thickness.

ELIZABETH HARTNER

Advanced Technique for Making Precision Castings*

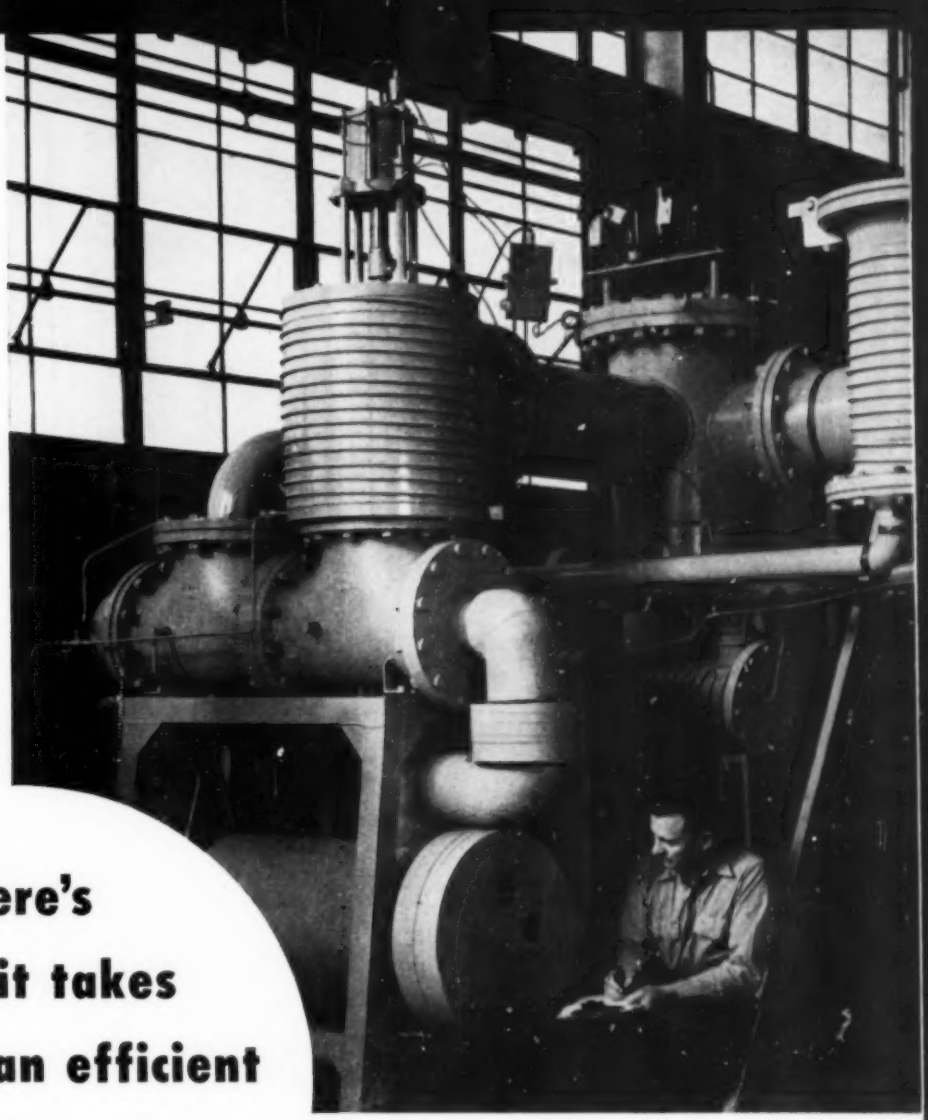
NEITHER SHELL MOLDING nor the investment casting process yields a precision product by today's machining standards, yet such castings as are being made are precise in comparison with conventional sand molding techniques.

Shell molding in a sense furnishes a bridge between the possibilities of static sand casting and investment casting. The method is now being used for castings up to about 25 lb. in weight. It involves a relatively expensive molding material, but this limitation can be offset by low-weight shells, increased casting accuracy with its lower machining costs, superior surface finish and the ability to form small, intricate cored sections difficult or impossible to produce in conventional sand molding. Dimensional accuracy devolves from the shell being formed *and cured* on an accurate metal pattern.

Selection of a sand for shell molding is based on various factors, principally the finish required, mold strength and permeability, differing,

(Continued on p. 198)

*Digest of "Making Castings by Shell Mold and Investment Processes", by R. R. Dohrmann, *General Motors Engineering Journal*, Vol. 1, September-October 1953, p. 8-12.



Here's what it takes to make an efficient *high vacuum* furnace

This is CVC's new Single-Stage Oil Ejector high vacuum pump, type KB-1500, designed especially for high pumping speed in the pressure range from 0 to 50 microns Hg. Wide jet clearances make this pump suitable for use on systems containing large amounts of dust or other impurities. It has an air removal rate of 2 pounds per hour at 50 microns, and can produce an ultimate vacuum of 5 microns Hg, while operating against a forepressure of .5 mm. Hg.

First, it takes unique high vacuum pumps that can remove large volumes of air and other gases rapidly and at low cost—pumps like the efficient Consolidated Vacuum type KB-1500 shown above.

Then, it takes solutions to such furnace design problems as handling more than one mold in the chamber, adding alloying elements to the melt, and charging the crucible without breaking vacuum. *CVC*, through years of *process equipment* design experience, can provide the answers to such problems.

Whatever your high vacuum metallurgical requirements, we can design and build a completely integrated system that meets your needs exactly. We welcome the opportunity to discuss your requirements with you. Write to ***Consolidated Vacuum Corporation, Rochester 3, N. Y.*** (a subsidiary of Consolidated Engineering Corporation, Pasadena, California).

CVC

Consolidated Vacuum Corporation

Rochester 3, N. Y.

formerly DPi Vacuum Equipment Dept.

designers and manufacturers of high vacuum equipment

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Crystal stability—the secret of success in production of an important new form of copper phthalocyanine blue pigment was achieved at American Cyanamid Company's Pigments Division through the use of the RCA Electron Microscope. Routine checks maintain particle size—help prevent crystal growth.

How the Pigments Division of American Cyanamid cuts $C_{32}H_{16}N_8Cu$ down to size

AT THE PIGMENTS DIVISION of American Cyanamid Company, research and production control are now important functions of the RCA Electron Microscope.

By determining the fine particle structure of pigments and finishes, Cyanamid engineers can set up physical standards for their products that were previously impossible.

With the RCA Electron Microscope, the pigment technologists can study particulate structure at magnifications up to 80,000X (200,000X, photographically). A variety of information that formerly was difficult to obtain, now can be developed in a matter of minutes with this important instrument.

Perhaps *your* quality control problems can be answered easily and quickly with the RCA Electron Microscope.

FOR INFORMATION about the RCA Electron Microscope and RCA's training assistance program, write Scientific Instruments, Dept B72, Radio Corporation of America, Camden, N. J.

SCIENTIFIC INSTRUMENTS
RADIO CORPORATION of AMERICA
ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.
In Canada: RCA VICTOR Company Limited, Montreal

Precision Castings

(Continued from p. 196)

of course, with different metals and casting designs. Coarse sands require less binder for adequate strength, but give a rough casting surface. A silica float sand of 115 A.F.S. fineness has been found a good general-purpose material.

Most commercially available shell mold powdered resins are comparable in quality and cost. Resin content is maintained at 6 to 8% of the sand weight. However, preliminary work has indicated that with a resin coated sand, contents as low as 3½% are satisfactory.

Refractory additives, such as iron oxide, aluminum oxide and silica flour are sometimes added where finish, mold reaction or metal penetration is a problem. Mixing is done in standard mulling equipment, with the addition of a wetting agent or light oil to suppress dust and improve resin distribution.

Patterns are usually of gray iron, sometimes of aluminum. Accuracy is all-important in shell pattern equipment which must compensate for metal shrinkage, mold shrinkage and ½ to 1° pattern draft.

Blowing of shells and cores is handled with a specially designed apparatus. The pattern is heated to 350 to 400° F. and is placed under a a blow head which is a female of the pattern, containing blow tubes and vents. Once blown, the green shell and pattern are removed to a curing oven which bakes the shell at around 800° in 1½ to 2 min. Higher temperatures induce objectionable warpage.

The cured shell is parted from the pattern by ejector pins in the pattern, after which the latter is cleaned with compressed air and sprayed with a parting compound before the next shell is made.

Blowing of shells has advantages of accurately filling intricate pattern sections and of forming a uniform shell thickness to enable the use of form-fitting backing frames. It also eliminates the need for pattern roll-over required in the dump-box method of shell preparation. Disadvantages of blowing are resin segregation and the lack of commercial equipment for automatic operation.

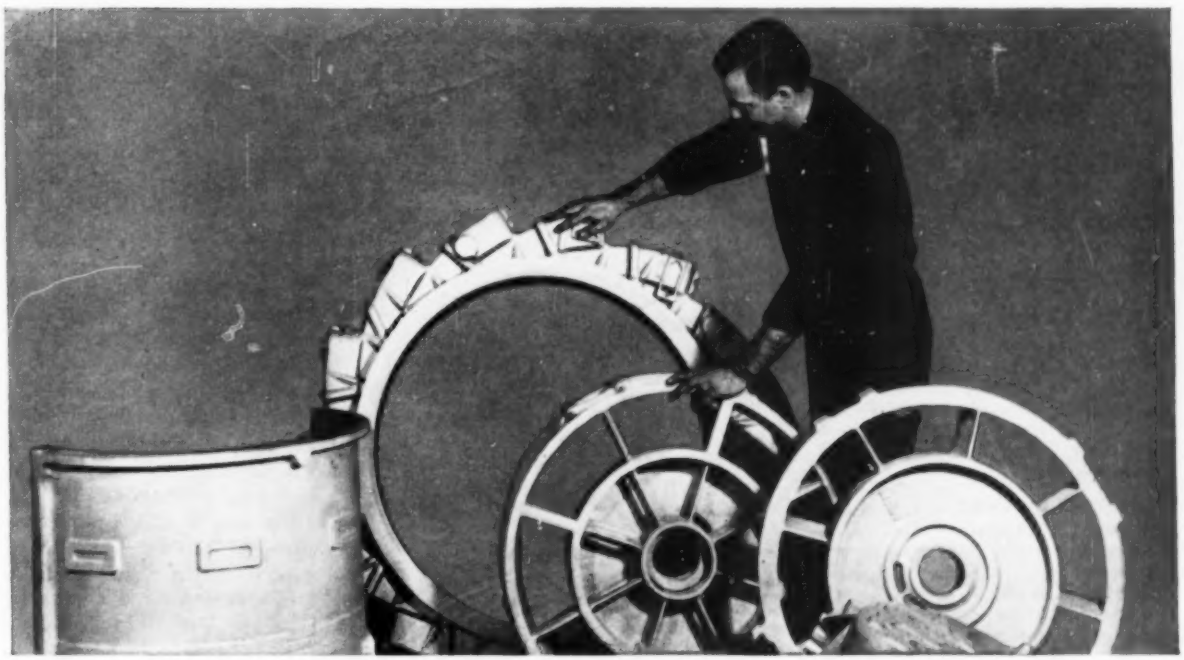
There are commercial machines using the dump process and produc-

(Continued on p. 200)

DOW

LIGHTER, MORE RIGID CASTINGS MADE WITH DOW MAGNESIUM

Production economies also offered by sand and permanent mold castings



Lighter, yet more rigid castings! That's the big advantage of magnesium in sand and permanent mold castings.

By increasing section thickness and adding stiffening ribs, greater rigidity is possible. And because of magnesium's high strength to weight ratio, total weight can be cut.

Magnesium also offers outstanding production advantages. Chief among these is magnesium's excellent machinability. There are many instances where time saved in machining has lowered the cost of the finished part beyond that of any other metal. Cutting tools last longer; replacement costs and downtime for sharpening and resetting are reduced.

Look, too, at the cost saving possible in handling. Magnesium's lightness can cut the costs of shipping, from raw casting to finished product. In-plant materials handling costs can also be reduced appreciably when lighter castings are used.

For further information on the advantages of magnesium, contact your nearest Dow sales office or write THE DOW CHEMICAL COMPANY, *Magnesium Department*, Midland, Michigan.

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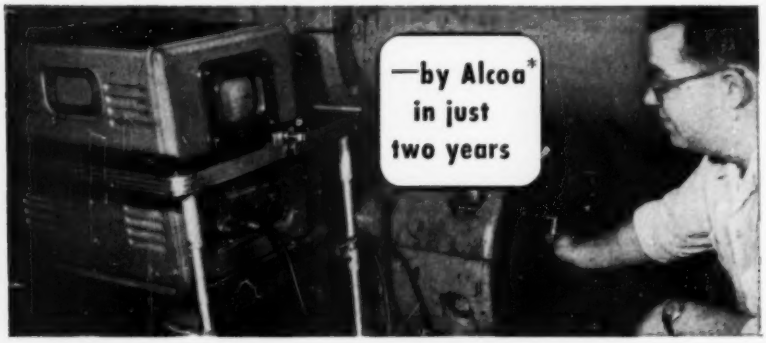

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OUR NEW BULLETIN 50-105 tells the whole story . . . just *how, where* and *why* the Ultrasonic Testing Reflectoscope can cut your costs from raw materials to finished product. To get your copy immediately, fill out and mail the attached coupon today.

* "We have had over two years experience in nondestructive testing with the Sperry Ultrasonic Reflectoscope. It has been used for the regular inspection of all our extrusion presses. Some 19 press columns have been removed before failure on data provided by the Reflectoscopes. The resultant savings in press damage and down time are estimated to exceed well over $1,000,000."
— Aluminum Company of America

TYPICAL TEST PATTERNS on Reflectoscope screen. At left, material O.K. At right, center "reflection" indicates and locates defect.

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Precision Castings

(Continued from p. 198)

ing shells automatically at a rate of 40 to 60 per hr. In this method of molding, a trunnion-mounted box contains the molding medium. The heated pattern is placed face down on the box, the box inverted for 15 to 30 sec. to allow the necessary shell build-up and then reinverted for removal of the pattern and shell to a curing oven.

Early methods of mold assembly and pouring involved gluing, stapling, taping or clamping, followed by embedding the assembly in sand or shot before pouring. Lack of sufficient strength to withstand the heat and hydrostatic pressure of the molten metal has led to perfection of a permanent backing apparatus, employing metal frames contoured to the reverse side of the shell. On gray iron castings, a backing of this sort gives dimensional accuracy of about ± 0.003 in. per in. on areas contained in one shell half and ± 0.007 in per in. across the shell parting line.

As mentioned before, shell molding is inherently expensive, since the high cost of the resin binders makes the molding medium four to five times as costly as dry sand. Cost of the shell mold mix is more than five times the cost of an oil sand mix.

Investment Casting – This technique is developed from the "lost wax" process widely used in the jewelry trade, and is applied commercially to small castings weighing 1 lb. or less. It requires rather expensive materials and processing. It yields castings of excellent surface finish and its dimensional accuracy stems from the use of an accurate, expendable pattern, plus a one-piece mold free from parting lines. However, minor surface imperfections usually occur and must be removed by polishing or machining. They may render the production of precision as-cast threads, for example, quite difficult.

The Fabricast Div. of General Motors Corp. has done extensive work of this sort on turbine buckets, blades and vanes for gas turbines, cast in heat resisting alloys generally regarded as neither forgeable nor machinable. Tolerances required on ¼-in. thick airfoil sections are ± 0.0075 in., with a true over-all spread

(Continued on p. 202)

Looking into the Blastmaster Barrel at Detroit Harvester. Abrasive-tight door has been opened for easy unloading. Note gleaming finish of cleaned pieces.

PANGBORN
BLASTMASTER BARREL
Cuts Cleaning Time 56%

And gives "finest finish" to the work for Henry and Allen Division of Detroit Harvester Co., Auburn, N. Y.

Formerly, the cleaning operation at Detroit Harvester required 44½ hours a week. Now a Pangborn Blastmaster handles all blast cleaning requirements in only 20 hours a week! So cleaning time has been cut 56%. In addition, labor costs have been reduced and experienced men are released for other work. Superintendent F. C. Palmer reports, *"We are highly pleased with the new Pangborn Barrel. It is very fast and thorough . . . saves money by cutting our blast cleaning job to less than half."*

Quality? Here's what Assistant Foreman Mike Hulik (with the company since 1912) has to say: *"This new Pangborn machine gives us the finest finish I have ever seen."*

The Blastmaster at Detroit Harvester is not an unusual installation. Blastmasters all over the country are winning commendations for fast, cost-cutting, *quality* performance on ferrous, non-ferrous and other metal castings. If *you* are interested in better, cheaper cleaning, it will pay you to investigate the Pangborn Blastmaster Barrel. Available in 4 sizes—3, 6, 12, or 18 cu. ft. capacities. For more details, write for Bulletin 223 to: PANGBORN CORP., 1800 Pangborn Blvd., Hagerstown, Maryland.

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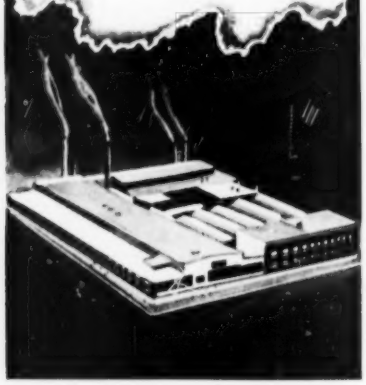

Precision Castings

(Continued from p. 200)

on castings more closely approximating ± 0.010 in.

Patterns are made of wax or plastic formed in precision dies on an injection molding machine. Soft metal dies usually are favored, with steel on long runs and for plastic injection. Both are relatively expensive.

A two-step investment, comprising a thin precoat backed by a coarse secondary material, is preferred in casting high-temperature alloys. Precoat is a formulated slurry of silica flour with a sodium silicate binder.

The investment medium is a refractory mixture of dead-burned fireclay, silica flour and minor percentages of an accelerator and a strengthening additive. Mold flasks are filled with the investment mix and placed on a vibrating table for about ½ hr. to drive out included air, force out excess binder and firmly pack the investment around the pattern. Molds are burned out, to release the pattern, and preheated in a gas-fired pusher furnace, the entrance end held at 600 to 900° F. and the exit end at 1600 to 1900° F. Time cycle is 6 to 8 hr.

Heat resisting alloys of the type used in gas turbine components require melting and pouring under an atmosphere with absolute temperature control. Melting is done in induction furnaces, with pouring effected by clamping the mold over the furnace crucible and inverting the furnace.

A. H. Allen

Highly Sensitive Dilatometer*

In an earlier report the author has discussed some of the potentialities offered by linear variable differential transformers as the sensitive element for a dilatometer. The present report describes experimental work in instrumentation which has resulted in two dilatometer units of

(Continued on p. 204)

*Digest of "Improved Precision Equipment for Metallurgical Analysis, Part I—Differential Transformer Dilatometer", by L. L. Wyman, U. S. Atomic Energy Commission Report KAPL-654, available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price 20 cents.

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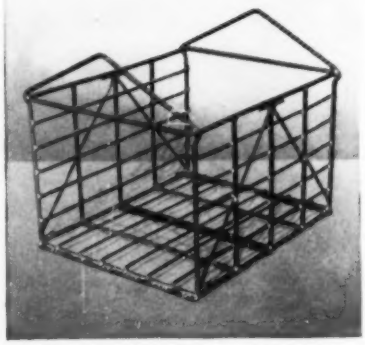

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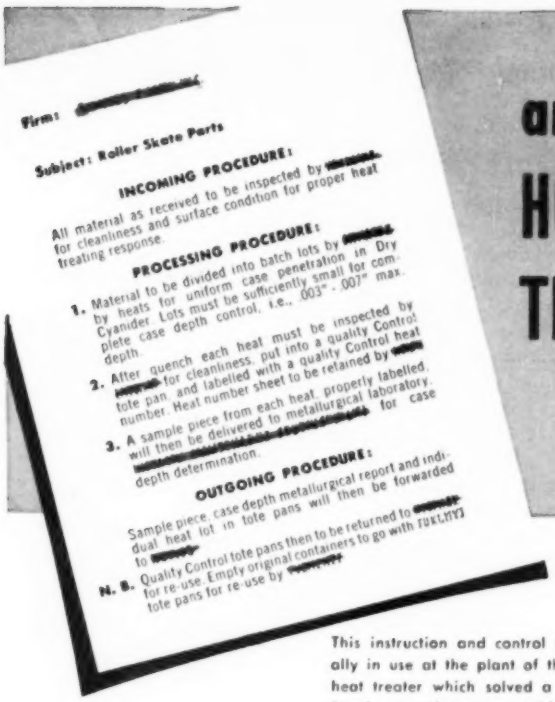

Firm: [redacted]

Subject: Roller Skate Parts

INCOMING PROCEDURE:

All material as received to be inspected by [redacted] for cleanliness and surface condition for proper heat treating response.

PROCESSING PROCEDURE:

1. Material to be divided into batch lots by [redacted] by heats for uniform case penetration in Dry Cyanider. Lots must be sufficiently small for complete case depth control, i.e., .003" - .007" max. depth.
2. After quench each heat must be inspected by [redacted] for cleanliness, put into a quality Control tote pan, and labelled with a quality Control heat number. Heat number sheet to be retained by [redacted]
3. A sample piece from each heat, properly labelled, will then be delivered to metallurgical laboratory [redacted] for case depth determination.

OUTGOING PROCEDURE:

Sample piece, case depth metallurgical report and individual heat lot in tote pans will then be forwarded to [redacted]

N. B. Quality Control tote pans then to be returned to [redacted] for re-use. Empty original containers to go with [redacted] tote pans for re-use by [redacted]

This instruction and control sheet is actually in use at the plant of the commercial heat treater which solved a real problem for the manufacturer as told here.

Recently a manufacturer of roller skate parts encountered a great deal of difficulty in trying to find a source of heat treating for a particularly hard job. So serious was the problem that at one time consideration was given to installation of the necessary equipment at the manufacturer's plant. However, equipment would have cost over $20,000 plus the additional expense of labor, plant space, insurance, supplies, and above all, the metallurgical supervision required to control this intricate work properly.

The manufacturer turned to a local commercial heat treater to handle the work and even offered to install the required equipment. However, they were able to handle the job to the utmost satisfaction of the customer, using existing facilities.

The cyaniding operation involved required a case depth of 0.003" to 0.007". Samples of each batch processed are sent outside to a commercial metallurgical laboratory for inspection and testing. After OK, the parts and metallurgical report for each batch are shipped to the customer. The control sheet shown here is actually in use at the plant now doing the work and conveys some idea of the thoroughness to be expected from those commercial heat treating plants which are members of the Metal Treating Institute.

A reprint of the article, "Heat Treaters Cite Short Cuts to More Effective Purchasing" is available from each of the companies listed. This handy reference will prove of value when ordering heat treating.

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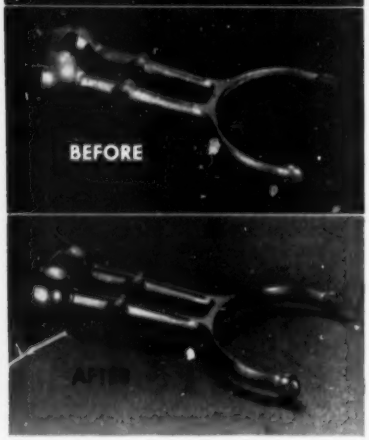

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Highly Sensitive Dilatometer

(Continued from p. 202)

a type which has given highly satisfactory results for many months in both continuous and intermittent operation.

A linear variable differential transformer (L.V.D.T.) is essentially a hollow cylinder upon which are several separate windings. One of the coils serves as the primary winding and two other coils as secondary windings, the unit constituting an air-core transformer. When the primary coil is energized with an alternating current of low voltage and a suitable iron or alloy core is inserted in the cylinder, the secondary windings become energized by the transformer thus formed. When the iron core is located in the exact center, a zero or null output from the secondary windings results since they are connected in opposition. If the core is displaced along the axis of the transformer, one of the secondary windings becomes more highly energized at the expense of the other secondary coil and the magnitude of the induced voltage is a linear function of the amount of displacement. Since the output voltage of the secondary windings can be amplified, the differential transformer provides a very sensitive tool for the measurement of small linear displacements such as those encountered in dilatometry. Relative merits of some L.V.D.T. units now commercially available are discussed in some detail by the author.

The use of differential transformers as sensitive elements has had some application in several fields, particularly in gages, accelerometers, and in a position indicator. The latter application was of particular interest because, properly adapted and developed, it might serve not only as the sensitive element of a dilatometer but could also (because its output is an emf. in the microvolt range) lend itself to the development of a simple yet highly sensitive device which would automatically produce a completed temperature-expansion curve.

Basically, the dilatometer developed consists of a "test" L.V.D.T. which is actuated by expansion of the dilatometer sample, a "balancing" L.V.D.T., amplifier, balancing motor

(Continued on p. 206)

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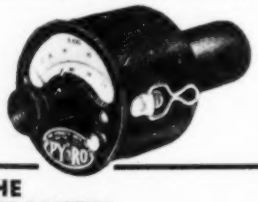

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Curtiss-Wright uses Westinghouse X-ray equipment for non-destructive testing of the important parts of their outstanding aircraft engines. The application pictured here shows the 250 KV X-ray tubehead, mounted on the jib crane tubestand, being positioned for the examination of the critical welds on gas turbine booster rotors.

The keynote for the selection of this equipment was *flexibility*—since *flexibility* results in more radiographs per shift.

1 Since the kilovoltage can be varied from 30-250 KV with greater X-ray output per KV resulting from the constant potential high voltage supply, the unit can be used to inspect materials from under ⅛" aluminum to 4" of steel.

2 The jib crane tubestand carries the tubehead from less than 3' up to 9' above the floor and from 50" to 14½' from the center of the vertical column which, in turn, can be rotated 135° in each direction. The tubehead mounting permits rotation of 180°, in either direction, around a vertical axis, and 140° around the long axis of the tubehead. The X-ray tube can be positioned easily and quickly to radiograph parts ranging in size from very small to very large.

Call your Westinghouse representative, or write to Westinghouse Electric Corporation, Industrial X-ray Section, 2519 Wilkens Avenue, Baltimore 3, Maryland.

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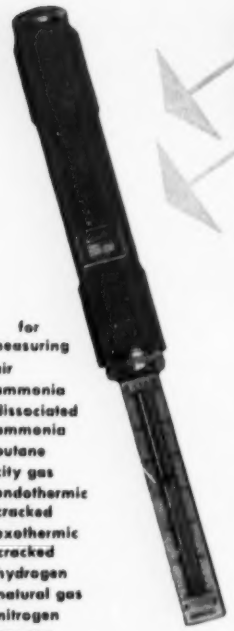

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TOOL COLUMBIA STEELS

Highly Sensitive Dilatometer

(Continued from p. 204)

and chart-type temperature recorder. The core of the "balance" coil is either screw or cam driven by the balancing motor itself and its output is placed in opposition to the output of the test coil, thus helping to stabilize the system. The difference in output is transmitted through the amplifier to the balancing motor which also drives the chart. The circuit arrangement is such that the interlocked balance coil and balancing motor always tend to drive the system in the direction which will attain a zero output of transformer voltages. A dilatometer sample which is expanding moves the transformer core of the test coil away from the zero position and the balance coil and motor combination tend to match this motion exactly in order to keep the system at the new balance. When the output of the balancing transformer is cut down by means of a voltage divider a larger movement of its core is required to match a given movement of the test coil. Since the record chart is inter-connected with the balance coil, the net result is a change in magnification of sample extension on the chart. For this purpose, a multi-range voltage divider assembled from calibrated resistors has proven quite satisfactory.

Regarding instrument design, such factors as the chart drive, voltage dividers, amplifier unit, operating head mechanism and operation and calibration of the dilatometer are covered in detail, as well as many of the experimental difficulties which were overcome along the way.

A large number of trial runs was made with this dilatometer using magnifications up to 1400×. Expansion curves for a high-purity iron subjected to at least half a dozen cycles up to 1970° F. at each of several magnifications were found to be quite reproducible. Surprisingly, for an instrument having such sensitivity and high magnification, it does not appear to be sensitive to vibration. The author reports that rapping the operating head sharply and repeatedly with a heavy ruler did not appear to disturb its operation. The resulting instrument is a direct-reading, instantaneous and constant

(Continued on p. 208)

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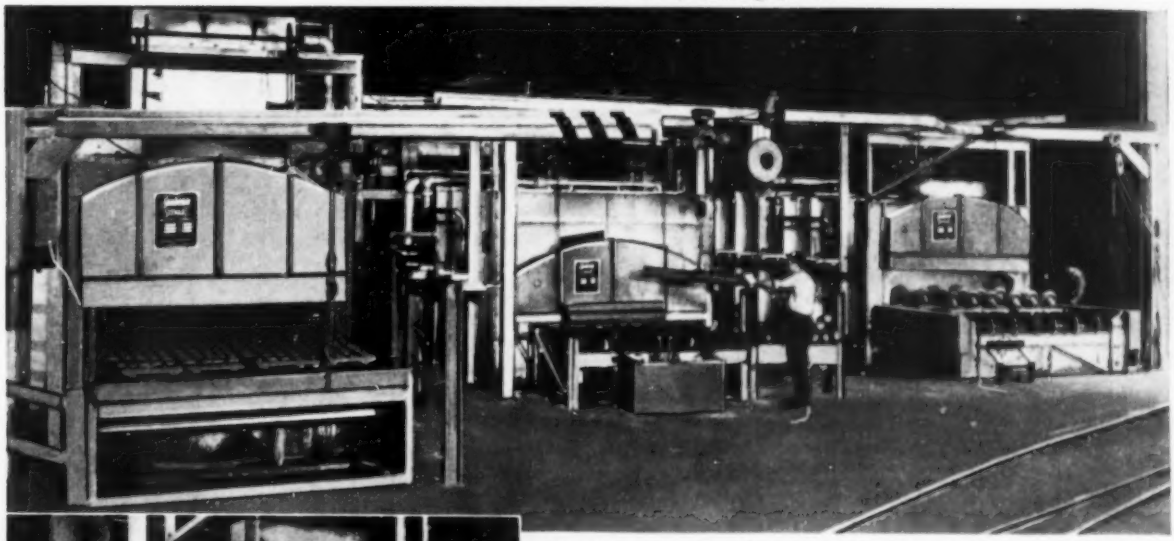
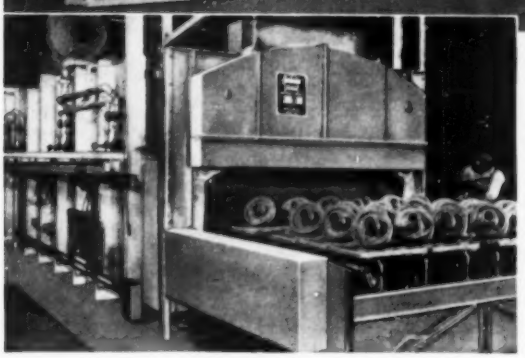


General view of the three integrated Sunbeam Stewart furnaces used for tempering, hardening and normalizing. The cycles in all three furnaces can be synchronized so that forgings make a continuous trip through all three furnaces.



Discharge end of the normalizing furnace showing the cooling table where forced draft is used to facilitate the cooling of normalized parts. The over-firing dual-fuel burners can be seen along the side of the furnace. A mechanical extracting mechanism is also built into the table. This extractor enters the end of the furnace (after pushing cycle is complete), lifts the forging and sets it on the cooling table.

To meet their production requirements for a special type of forging, Kropp Forge of Chicago have been using Sunbeam Stewart furnaces for normalizing, hardening, and tempering. The normalizing furnace, a double row pusher type furnace, is 18" high by 90" wide by 32½' long (inside dimensions) and has a rated capacity of 6500 lb. per hr. The furnace is separated into two zones by a cooling chamber near the center of the furnace. This section does not contain any burners, but does have a fan which can blow cold air into the furnace through multiple openings to air cool the material in the furnace. The hardening furnace is a duplicate of the normalizing furnace, with the exception that there is no cooling zone in the center. The furnace is divided into two zones of control, 5 burners in each zone. There is a quenching tank and manipulator at the discharge end of this furnace. A quenching tank 7' in diameter by 10' deep is located slightly below floor level at the discharge end. A recirculating, double rail pusher type furnace is used for tempering forgings. The heating chamber in the furnace is 18" high by 90" wide by 45' long. This furnace has a rated capacity of 8500 lb. per hour.

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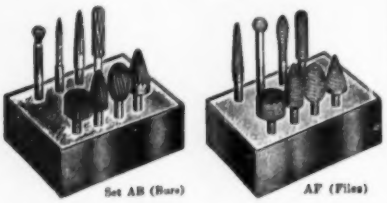

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Highly Sensitive Dilatometer

(Continued from p. 206)

curve-drawing, temperature-expansion recorder. If properly installed the operating head may be located up to 5000 ft. away from the controlling and recording parts of the instrument. It is further stated that, from the operational standpoint, the instrument is simple, rugged and amenable to a wide range of magnifications. G. M. SINCLAIR.

Ductility of Pure Chromium*

THIS PAPER presents an interesting study of the mysterious lack of ductility shown by the purest forms of chromium metal, and describes an investigation of some properties of highly purified chromium.

The most important factor in this investigation was the preparation (a tedious operation) of the purest possible form of chromium. Electrolytic chromium, which ordinarily contains about 0.06 Fe, 0.007 N_2, 0.026 S, and less than 0.01% Si, was used as the base metal. The electrolytic chromium was ground for 10 days in a ball mill using steel balls to obtain a powder of very fine grain. Since this grinding operation causes a contamination by the iron from the grinding balls, the powder was simmered for 10 days in a 50% nitric acid solution. Most of the iron was dissolved and the final product contained less than 0.02% Fe. After milling and simmering, the chromium powder was compressed under 44,000 psi. into compacts 2½ in. long, ½ in. wide and 0.2 in. thick. These were sintered at 2640° F. for 4 hr. in an atmosphere of dry hydrogen. The resulting material contained 0.01 to 0.02% O_2, less than 0.02% Si and less than 0.02% N_2 and Fe, and total purity was estimated to be 99.90%.

The sintered compacts of the dimensions given above were then subjected to bending tests to de-

(Continued on p. 210)

*Digest of "The Effect of Temperature and Purity on the Ductility and Other Properties of Chromium", by A. H. Sully, E. A. Brandes, and K. W. Mitchell, *Journal* of the Institute of Metals, Vol. 81, August 1953, p. 585-597.

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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

LOOKING AHEAD IN CARS AND CASTINGS

RE: CARS

MR. LAWRENCE POMROY, F.R.S.A., M.S.A.E., internationally respected Technical Editor of THE MOTOR, British automotive publication, offers comment and pregnant predictions in the December 16th issue. One of his 1939 predictions dead-on-the-nose was that the best all-around small car should have: 1) independent four-wheel springing, 2) improved weight distribution by employing (a) V engine, far forward, (b) integral clutch-transmission-differential assembly.

THIS describes the light weight (3.1 litre, 140 b.h.p. engine (about 15% under Ford size) Lancia sports cars, that won 1st, 2nd, 3rd in the 1953 1,913 mile Mexican road race (leading the 3 winning "stock" class Lincolns by over two hours), and we're damned proud of those Lincolns).

APPROACHING the next fifteen years, Pomroy writes:

"IT IS unlikely that anything will be catalogued then which cannot be seen in embryo now.

"IN SEEKING practical examples of the future in the world of today, we do not find any clear guidance by viewing the American so-called 'Cars of Tomorrow'.... But proposals to provide 300 b.h.p. to propel a mass of 2½ tons through automatic gearboxes are wildly out of line with world political and social trends, both of which abstract increasing percentages of national productivity for communal needs, such as jet bombers, health services, television and even opera and ballet.

"THIS lessens private purchasing power to an extent which is, even today, and even in England, still under-rated. As a concrete example: the taxation raised to finance the development, merely (excluding tooling-up and production costs), of the Proteus and Avon series of aero engines, would have bought 120,000 Ford cars. The car of tomorrow must interpret such economic facts.

"HENCE we shall expect to see development concentrated upon the most efficient use of the materials built into the car, and of the fuel and oil used subsequently to drive it.... The logical development here, therefore, must be to use a vee-type engine with the gearbox, and possibly the clutch also, on the back axle ... (Ed. Note: Ditto his 1939 prediction now seen in the Lancia Aurelia)

"IT is, on the face of it, not impossible to build a 100 h.p. 3-litre car on a wheelbase of 8 ft. and even at the expense of coefficient of penetration it will probably be best to reduce fore and aft overhang to get easy parking and the lowest possible weight. With reasonable shape a speed of 100 m.p.h. should be obtained whilst if the weight could be held down to around 2000 lbs., then a simple gearbox with a fluid flywheel would give an efficient transmission in which the driver could change speeds without having to press a clutch pedal.

"ALTERNATIVE ASPECTS:

"TO make the most of die costs and tool charges, it would be reasonable to build a lower-powered version of this basic car with a four-cylinder engine of slightly greater bore and stroke, giving a swept volume of, say, 1.8 litres. If this gave, say, 55 h.p., the maximum speed of the car would drop to a little over 80 m.p.h., and this would be quite fast enough for all ordinary drivers.... maximum gradient climbable on top gear could be about 1 in 11 with the smaller engined car as compared with, say, 1 in 8.5 on the larger and higher geared model."

RE: CASTINGS

IF THE record of predictions which have come to pass is considered as prophetically qualifying, then our GA predictions which follow may be acted upon by thinking men.

It is recalled that General Alloys exhibited a clock which kept time at 2,000° for one week at the National Metal Show in Philadelphia in 1928, a decade before the so-called "precision" casting processes were expanded out of the dental and jewelry field into superchargers, jet engines and industry. To this date, however, no other comparably complex mechanical movements or assemblies have operated at high temperatures. The challenge, to designers, of *full employment of advanced casting design-process technology* has not been accepted.

We predict: a material increase in the use of castings in aircraft engines through advances in casting design-process technology, largely pioneered by General Alloys during World War II.

We predict: that the casting of "donut" alloy ingots in permanent molds and rerolling same on tire mills will revolutionize air engine production. In fact, it will save about $15,000 per day for one manufacturer. (This process was conceived and projected by GA and was largely developed under a USAF Air Materiel Command contract by GA in 1944-45.)

We predict: a high percentage of jet turbine components now fabricated from sheet will be produced by "flow-turning" (a "super-spinning" operation, in which the "bow-wave" does the work) from fine grain, non-stratified, cast tubes. (The first, and to date, the best process for producing such castings in HR and CRS alloys was developed jointly by General Alloys, Ford Motor of Canada, and Alloy Engineering and Casting Company who together supplied the only such castings in World War II.)

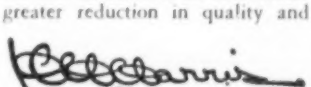
We predict: that a large number of cast aircraft components will replace forgings and fabrications with equal or superior strength-weight ratio and functional ability at reduced cost. (Produced by advanced processes projected from General Alloys developments, recently and currently, projected to pilot production by Navy and Air Force sponsorship.)

We predict: that the excessive mixing of oxides in light metal castings can and will be eliminated with a 50% plus improvement in physical properties.

We predict: that modern stress testing procedures will be broadly applied in casting design and that advanced casting design-process technology will clearly demonstrate the *inherent advantages of continuity of form and mass* (which increase with size, and are best attainable with least limitation and cost by pouring metal direct to size). Certainly a single homogeneous piece contoured proportionally to load is superior to an assembly of bits and pieces.

We predict: that castings in large sizes will be volume produced with dimensional tolerance to largely, or entirely, eliminate machining. *When, where and how soon* these predictions come to pass is a matter for *you* to decide if they can benefit your operations. Your consultation is invited without obligation.

We predict: that no alloy prices will be reduced in 1954 metal and labor markets, without greater reduction in quality and service.



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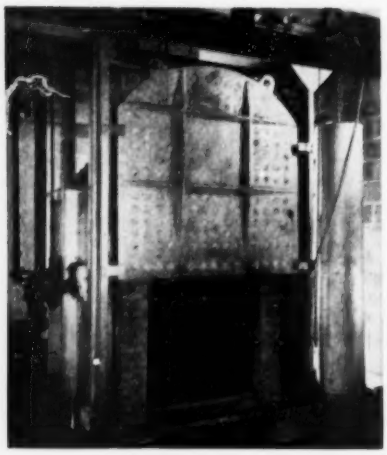

This car-type annealing furnace is an example of the heat treating furnaces designed and engineered by the Carl-Mayer Corp. This particular car bottom furnace was designed for the heat treatment of chain up to 2000°F. at Cleveland Chain & Mfg. Co. We also build furnaces for other uses, including aluminum and magnesium heat treating.

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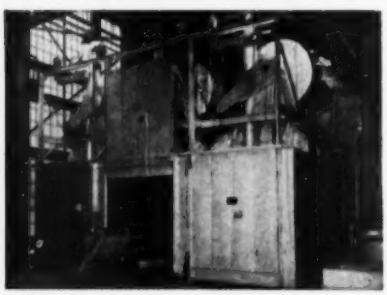

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Ductility of Pure Chromium

(Continued from p. 208)

termine the stress and temperature at which a brittle fracture occurred. The distinction drawn between brittleness and ductility was determined by the authors as the point at which fracture occurred in the elastic region. All of the different forms of purified chromium studied exhibited a sharp transition temperature from a ductile to a brittle fracture in the bend test. Usually, the variation did not amount to more than 5 or 10° for the different specimens of the same purified batch but each lot showed a different transition temperature. Transition temperature for the sintered purified electrolytic chromium ranged from 131 to 194° F., but for chromium specimens obtained from hydride chromium the range was from 464 to 752° F. The purity of hydride chromium is much less than that of the electrolytic chromium used in this investigation. Interesting diagrams are contained in the paper which show bending deflection and impact properties.

Tensile test specimens of 0.179 in. diameter were ground from the sintered compacts. The tensile stress of the chromium was 14,870 psi. at 68° F., 13,680 at 930° F., and 11,400 psi. at 1650° F. The elongation and reduction of area were zero at both 68 and 930° F., whereas the test at 1650° F. gave 3% elongation and 2% reduction of area. Even at this high temperature the ductility of this metal is extremely low.

A long discussion of the effects of various elemental impurities on the properties of the chromium is contained in the paper. The authors conclude that the effects of oxygen and nitrogen on the ductility must be negligible because samples containing less than 0.01% O_2 exhibited the same degree of brittleness and the same transition temperatures as those containing 0.87% O_2. No variation in ductility was found for specimens containing 0.001% N_2 and those containing 0.004% N_2.

Varying amounts of silicon, iron, aluminum, manganese, cobalt, tungsten and copper were added to the sintered and purified chromium metal. It was always found that additions of these impurities in

(Continued on p. 212)

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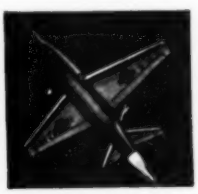

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Ductility of Pure Chromium

(Continued from p. 210)

amounts varying from 0.05% Al to 3.4% Mn raised the transition temperature at which brittleness became apparent.

Microscopic examination of the broken pieces showed quite clearly that practically all of the fractures were of a transcrystalline nature. This seemed to hold true for the slow bend test and the rapid impact test.

Other physical properties of purified chromium discussed are Young's modulus, internal friction, coefficient of expansion and resistivity. Although the authors did not investigate these physical properties, they quote from the paper by Fine, Griner, and Ellis and also reprint their diagrams which show that these four properties have a sharp transition point at 98° F. The authors measured the lattice parameter of the purified electrolytic chromium in a temperature range of 68 to 480° F. A straight-line curve showing the increase of this dimension with temperature and having no discontinuity in the neighborhood of 98° F. (discontinuous changes occur at this temperature for the four properties) is taken as indication that no internal change in lattice occurs at this transition temperature even though the physical properties of the metal change so drastically.

It is pointed out that even though the chromium specimens were prepared by the careful methods described, a sharp transition from a ductile to a brittle cleavage fracture takes place in the elastic range over a range of a very few degrees in temperature. Similar behavior has been observed in iron, tungsten, and molybdenum, which also crystallize in a body-centered cubic system. The conclusion reached from this work is that the brittleness of chromium is an example of the more general phenomenon of the strong dependence of ductility on temperature which is apparent in all body-centered cubic metals. The fundamental reason for this is still obscure, and the question arises as to whether it is due to the small content of impurity still present even when these metals have been purified to the greatest extent possible with existing techniques. E. C. WRIGHT

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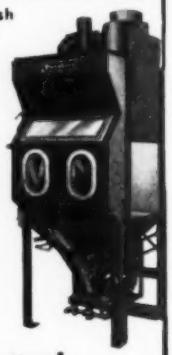

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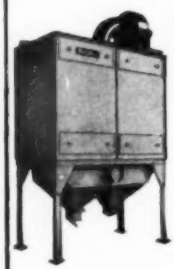

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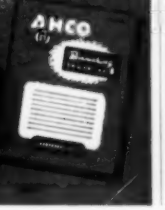

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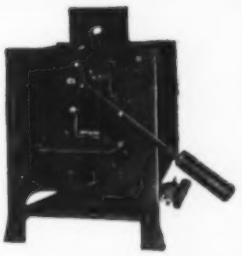

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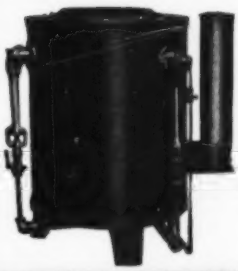

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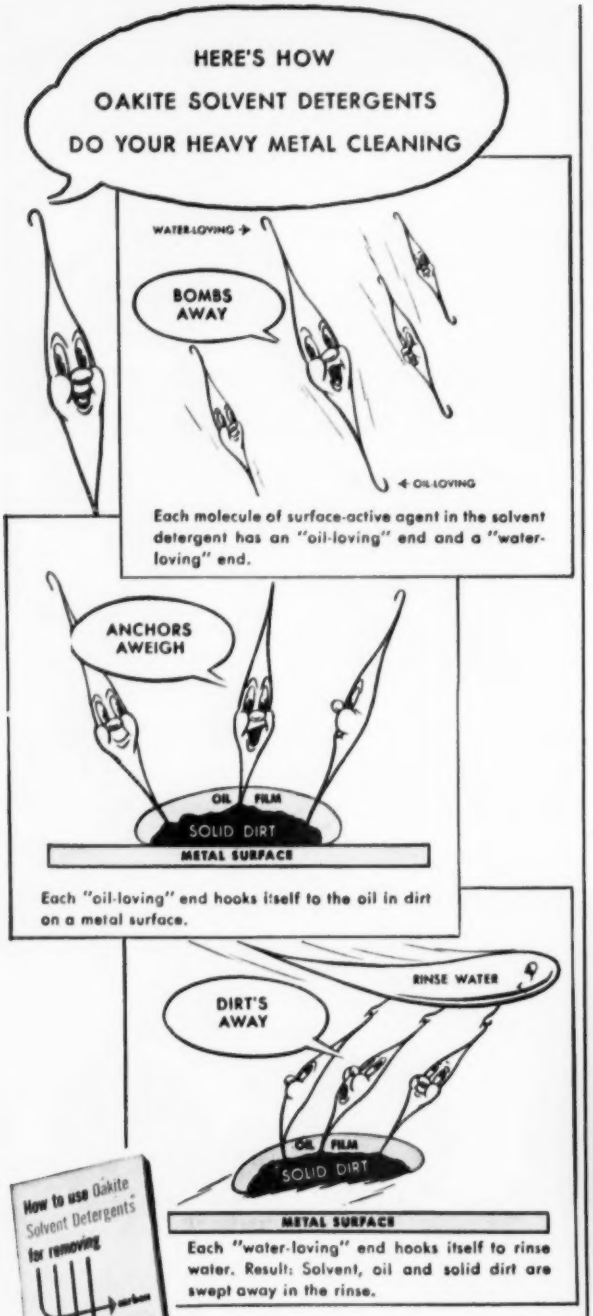
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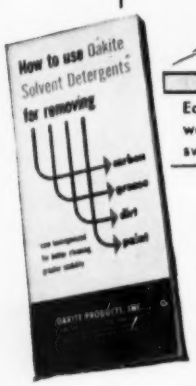

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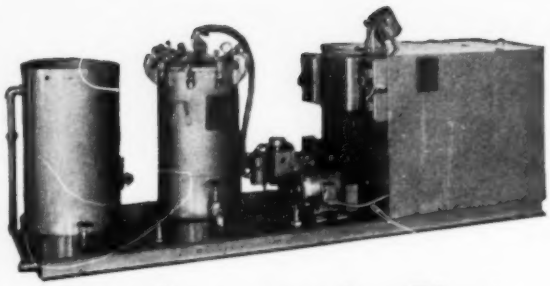

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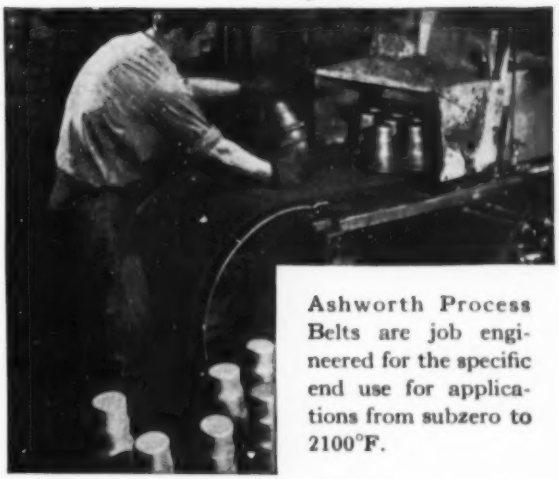

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• Index to Advertisers •

Acheson Colloids Corp. ..... Back Cover
Ajax Electric Co. 37
Ajax Electrothermic Corp. 133
Aldridge Industrial Oils, Inc. 146, 154
Allied Research Products, Inc. 130
Alloy Engineering & Casting Co. 128B
Almco Div. 150
Alpha Corp. 154
Alvey-Ferguson Co. 15
American Chemical Paint Co. 140
American Cyanamid Co. 96C
American Gas Association 34
American Gas Furnace Co. 135
American Machine & Metals, Inc. 12
American Non-Gran Bronze Co. 153
American Optical Co. 168
American Platinum Works 129
American Radiator and Standard Sanitary Corp. 131
American Roller Die Corp. 149
American Smelting & Refining Co. 177
American Society for Metals 181
Amplex Division Chrysler Corp. 139
Apothecaries Hall Co. 213
Armour & Co., Ammonia Div. 43
Armstrong-Blum Mfg. Co. 194
Arwood Precision Casting Corp. 22
Ashworth Brothers, Inc. 215
Atlantic Chemicals & Metals Co. 154
Atlas Mineral Products Co. 136

Babcock & Wilcox Tubular Products Div. 32
Baker & Co., Inc. 202
Barber-Colman Co. Wheelco Instruments Div. 32B
Bausch & Lomb Optical Co. 96D
Bel-Ray Co., Inc. 154
Bethlehem Steel Co. 35, 54
Bigelow-Liptak Corp. 32F
Boder Scientific Co. 156
Bowser Technical Refrigeration 170
Branson Instruments, Inc. 156
Bristol Co. 40
Brooks & Perkins, Inc. 182
Buehler, Ltd. 16D

Cambridge Wire Cloth Co. 202
Carborundum Co. 115
Carl-Mayer Corp. 210
Carlson, Inc., G. O. 128
Carpenter Steel Co. 119
Chace Co., W. M. 190
Chase Brass & Copper Co. 52
Cincinnati Milling Machine Co. 183
Circo Equipment Co. 172
Cities Service Oil Co. 39
Clark Instrument Co. 29
Cleveland Crane and Engineering Co. 151
Cleveland Metal Abrasive Co. 151
Climax Molybdenum Corp. 212
Columbia Tool Steel Co. 206
Consolidated Vacuum Corp. 197
Continental Industrial Engineers, Inc. 196
Cooley Electric Mfg. Corp. 146
Cowles Chemical Co. 127
Crucible Steel Co. of America 17, 167, 187

Drakin & Son, J. Arthur 155
Dempsey Industrial Furnace Corp. 148
Detroit Testing Machine Co. 155
Dice Co., J. W. 135
Dow Chemical Co. 199
Drever Co. 24
Driver-Harris Co. 195
Du-Lite Chemical Corp. 150
duPont de Nemours & Co., Inc. 63, 123

Eclipse Fuel Engineering Co. 215
Ekstrand & Tholand, Inc. 153
Electric Furnace Co. ..... Inside Back Cover
Electro Alloys Div. American Brake Shoe Co. 2
Electro Metallurgical Co. Unit of Union Carbide and Carbon Corp. 111
Engineered Precision Casting Co. 153
Erico Products, Inc. 152
Ethyl Corp. 31

Finkl & Sons Co., A. 49
Foxboro Co. 42

General Alloys Co. 209
General Dyestuff Corp. 50
General Electric Co. 173
General Electric Co., X-Ray Dept. 44
Gordon Co., Claud S. 210
Great Lakes Carbon Corp. 213
Great Lakes Steel Corp. 41
Gries Reproducer Corp. 153
Gulf Oil Corp. 6-7

Hangsterfer's Laboratories 154
Harper Electric Furnace Corp. 166
Haynes Stellite Corp. Unit of Union Carbide & Carbon Corp. 137
Hays Corp. 146
Hevi Duty Electric Co. 23
H & H Tube Co. 189
Himmel Brothers Co. 152
Holcroft & Co. 32A
Hones Inc., Chas. A. 213
Hoskins Mfg. Co. 211

Illinois Testing Laboratories, Inc. 180
Industrial Filtration Co. 9
Institute of Metals 215
International Nickel Co. 47, 96A
Ipsen Industries, Inc. 45

Jelliff Mfg. Corp., C. O. 150
Jet Combustion, Inc. 118
Johns-Manville 138
Jones & Laughlin Steel Corp. 61

Kennametal, Inc. 144
Kent Cliff Laboratories 156
Kinney Mfg. Co. 164

Lakeside Steel Improvement Co. 149
Latrobe Steel Co. 32C
Lavin & Sons, Inc. 193
Leeds & Northrup Co. 8
Lepel High Frequency Labs. 56
Lindberg Engineering Co. 53
Lindberg Steel Treating Co. 149
Little Falls Alloys 152
Little, Inc., Arthur D. 60
Lord Chemical Co. 204
LR Heat Treating Co. 148

Magnethermic Corp. 32E
Magnetic Analysis Corp. 155
Mahon Co., R. C. 192
Malayan Tin Bureau 36
Manhattan Rubber Div., Raybestos-Manhattan, Inc. 151
Marshall Products Co. 126
Martindale Electric Co. 208
Maurath, Inc. 153
Meriam Instrument Co. 155
Merrill Bros. 208
Metal Carbides Corp. 163
Metallizing Co. of America 214
Metal Treating Institute 203
Michigan Steel Casting Co. 124
Minneapolis-Honeywell Regulator Co. (Industrial Divis'on) 4-5, 32D
Mitchell-Bradford Chemical Co. 114
Murray-Way Corp. 48

National Carbon Co. Unit of Union Carbide & Carbon Corp. 191
National Machinery Co. 121
National Metal Abrasive Co. 28
National Research Corp. 160B
Newage International, Inc. 214
Niagara Alkali Co. 58
Niagara Blower Co. 132
Nitrogen Division Allied Chemical & Dye Corp. 46
North American Mfg. Co. 125
Northwest Chemical Co. 165
Norton Co. 26

Oakite Products, Inc. 214
Ohio Crankshaft Co. 157
Ohio Seamless Tube Co. 20
Optical Film Engineering Co. 27

Pangborn Corp. 201, 212
Park Chemical Co. 33, 150
Perény Equipment Co. 28
Picker X-Ray Corp. 55
Pittsburgh Lectrodryer Corp. 141
Pittsburgh Plate Glass Co. 46
Pressed Steel Co. 113
Production Specialties, Inc. 154
Puritan Mfg. Co. 150
Pyrometer Instrument Co. 204

Ra-Diant Products Co. 146
Radio Corp. of America 198
Raybestos-Manhattan, Inc., Manhattan Rubber Div. 151
Republic Steel Corp. 57, 62
Revere Copper & Brass, Inc. 117, 169
Reynolds Metals Co. 51
Richards Co., J. A. 152
Roll Formed Products Co. 152
Rolock, Inc. 159
R-S Furnace Corp. 184-185
Rubicon Co. 25
Ryerson & Son, Inc., Jos. T. 64

Salem-Brosius, Inc. 144A
Sandvik Steel, Inc. 173
Sargeant & Wilbur, Inc. 122
Scherr Co., Inc., George 19
Seymour Mfg. Co. 30
Sherman Industrial Electronics Co. 148
Sivyer Steel Casting Co. 179
Solventol Chemical Products, Inc. 3
Spencer Turbine Co. 143
Sperry Products, Inc. 200
Steel City Testing Machines, Inc. 174
Standard Alloy Co., Inc. 120
Standard Steel Treating Co. 149
Stanwood Corp. 146
Star Stainless Screw Co. 153
Stuart Oil Co., D. A. 59
Sub-Zero Products, Mfg. Div. 186
Sunbeam Corp. 207
Sun Oil Co. 14
Superior Tube Co. 144B
Superior Steel Corp. 128A
Surface Combustion Corp. ..... Inside Front Cover
Swan-Finch Oil Corp. 28
Swift Industrial Chemical Co. 148, 151
Sylvania Electric Products, Inc. 178

Taber Instrument Corp. 155
Taylor Sons & Co., Chas. 160
Thermo Electric Co., Inc. 176
Timken Roller Bearing Co. 11
Titan Metal Mfg. Co. 160A
Turco Products, Inc. 171

Union Carbide & Carbon Corp. 111, 143, 191
Unitcast Corp. 134
United States Steel Corp. ..... 16A, B, C
Upton Electric Furnace Co. 147

Vanadium Corp. of America 10

Waukee Engineering Co. 206
Webber Appliance Co. 16
Western Products, Inc. 147
Westinghouse Electric Corp. 205
West Instrument Corp. 18
Wheelco Instruments Div., Barber-Colman Co. 32B
White Metal Rolling & Stamping Corp. 152
Wilson Mechanical Instruments Div., American Chain & Cable 142

Yoder Co., The 158
Young Brothers Co. 188
Youngstown Sheet & Tube Co. 38

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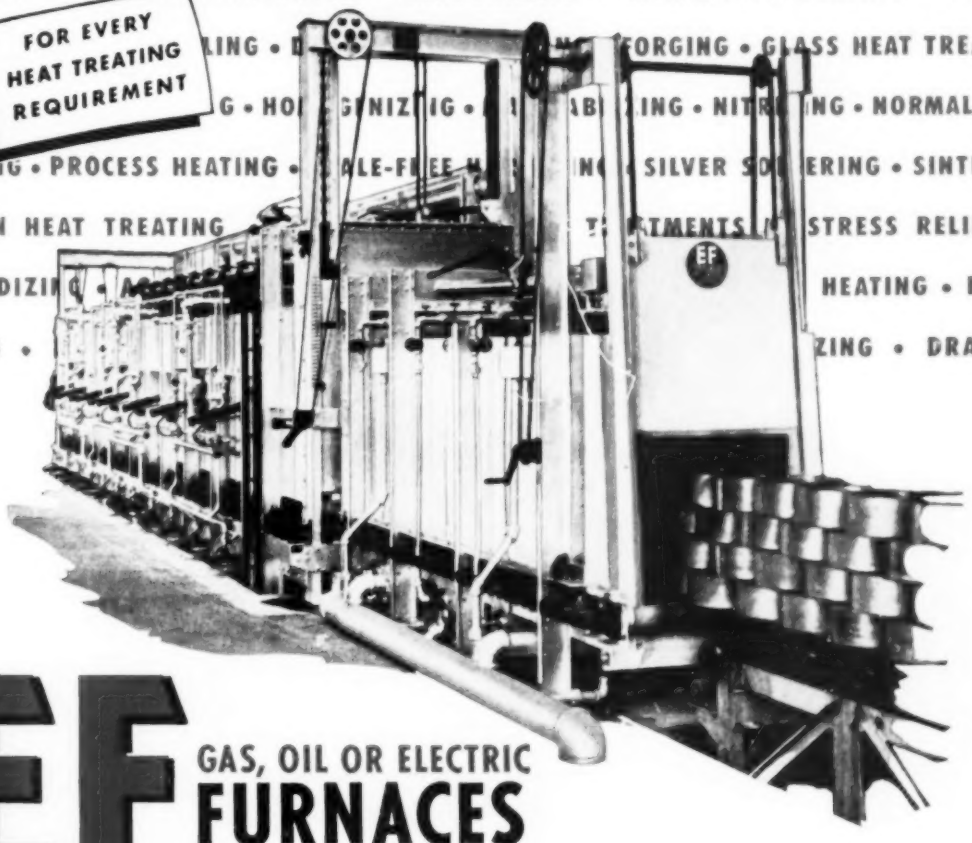

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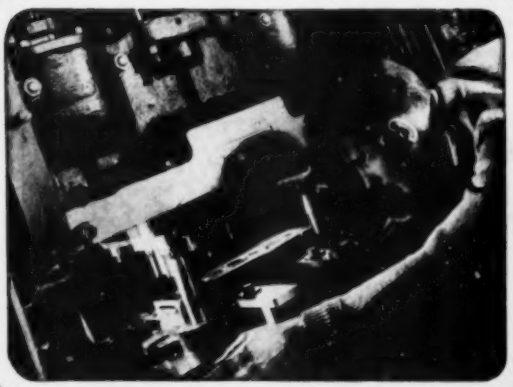

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